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Vol. 181 FEBRUARY, 1916 No. 2

THE RÔLE OF CHEMISTRY IN THE WAR.*

BY

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Member of the Institute.

THE human race is living at the bottom of an ocean of atmosphere some six to seven miles deep. Although it is not always realized by the unscientific mind, this aërial sea has weight and exerts a pressure upon all bodies of approximately fifteen pounds to the square inch. Roughly speaking, and disregarding a small amount of rare gases and impurities, the air consists of about one-fifth oxygen and four-fifths of the inert gas nitrogen.

Every intelligent person knows that oxygen is the breath of life, and that nitrogen serves the purpose of just sufficiently diluting the oxygen so that the combustion of waste carbon conveyed by the blood to the body tissues goes on at the steady rate which conforms to the life processes of all animals. With this general knowledge in regard to the element nitrogen, the ordinary, well-informed, non-technical man rests content.

Educated people are, of course, aware that fixed nitrogen in combination with carbon, hydrogen, and some few other minor elements is built up by vegetable life and, in turn, assimilated into the bodies of animals, thus supplying our food of almost every variety. It is also fairly well understood that in the processes of digestion the complex nitrogenous bodies built up by plant life

* Communicated by the Author.

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are broken down to simpler forms, in part supplying animal life energy and in part being voided by the animal, the manurial nitrogen products going back to the soil, thus completing what is known as the nitrogen cycle, caught in the wheel of which all material life, including the much-vaunted culture and progress of modern civilization, hangs suspended.

One thing that is not very generally apprehended by educated people, however, is that without fixed nitrogen in great abundance mankind could not wage war upon one another under modern conditions. Ever since gunpowder replaced the bow and arrow, fixed nitrogen has been used by man to hurl destructive missiles at his adversaries. In fact, it should be stated that no explosive substance has ever been used in peace or war which did not depend for its activity on the extraordinary properties of the element nitrogen, which, as the major constituent of the air we breathe, could almost be said to content itself with the inert and pacific rôle of toning down the activities of its restless neighbor, oxygen.

I.

THE RÔLE OF NITROGEN.

It becomes evident, from what has been said, that there must be some vital and important difference in character or quality between what may be termed *fixed* and *unfixed nitrogen*. In other words, it should be understood that all life and phenomenal existence, on this planet at least, depend upon the simple fact that the element nitrogen is able to assume two rôles, in one of which it is unfixed, inert, sluggish, and slow to enter into combination with other elements, and in the other of which it is active, reactive, restless, ever ready to break down into new combinations, absorbing and giving out enormous energy as the restless changes take place. Whether the changes take place in a measured and orderly fashion, as in plant-cell growth and animal digestion, or with the most sudden and terrible violence, as in the case of high explosives, the energies either absorbed or released are equally potent and measurable. The celebrated chemist Berzelius once said of the element nitrogen as it occurs in the air, it is difficult to recognize by any conspicuous property, but can only be recognized by means of properties which it does not possess.

Before pursuing our subject further, it will be necessary to make quite clear what is meant by inert, unfixed nitrogen and

active or fixed nitrogen. This explanation must be made in such a way that all apparent contradictions will immediately disappear. Gaseous nitrogen as it exists in the atmosphere has been proved by scientific methods to consist of a molecule made up of two atoms bound together by the equivalent of three bonds of affinity. What is meant is made clearer if we write a sort of alphabetical expression of the inert nitrogen molecule, as follows:

$$N \equiv N$$

It should not be supposed that the three bonds are actually arms or linkages holding the atoms together; they simply represent actually existent atomic forces, so that we may say that the element nitrogen is trivalent. In the same way we know that the element hydrogen is univalent, and we may express this by writing H – H, for the molecule of hydrogen is also known to be diatomic.

Now, suppose that by some means it is desired to combine or fix nitrogen to hydrogen; it is at once apparent that we should have to expend energy to tear apart the molecular bonds before we can fix the two elements together. In other words, the $N \equiv N$ would have to pass through the condition $N \equiv$ and $\equiv N$. Similarly, the H – H would have to split up into H – and – H. Subsequently, the two elements might combine to form ammonia,

$$\begin{array}{c} -H \\ N-H. \\ -H \end{array}$$

For the purpose of this paper it is not necessary to go deeper into the combining valences of the different elements which it will be necessary to discuss. Only the simplest combination of nitrogen and hydrogen, viz., ammonia, has been mentioned in order to show the difference between fixed nitrogen and the inert or unfixed state of this gas as it exists in the air, with all its chemical affinities self-satisfied; in short, in the condition $N \equiv N$. If, however, this union is torn apart, $N \equiv$ is in an actively unsatisfied state and is prepared to fix itself into myriads of combinations with other elements. In other words, the molecule of nitrogen is quiet and well behaved, whereas the free atom of nitrogen is dynamically and even, in some combinations, very terribly reactive. It is this underlying chemical fact that has enabled men

to slaughter and destroy each other on the gigantic scale now being demonstrated.

Those who have followed this explanation will readily see that it is not possible to maintain nitrogen in the condition of free unsatisfied atoms ($N\equiv$), for the simple reason that these atoms would return to the stable, quiescent molecule ($N\equiv N$), possibly with explosive energy. In order to take advantage of the reactive condition, it is necessary to lightly fix the nitrogen atom to some other atoms or groups of atoms in such a manner or in such a combination that the nitrogen at a blow can be suddenly released. Let us take the simplest example of what is meant. By an experiment so simple that the merest tyro in chemistry can perform it, ammonia can be made to react with the univalent element iodine to form the compound known as nitrogen iodide, in which iodine is made to replace the hydrogen, so that

$$\begin{matrix} -H \\ N-H \\ -H \end{matrix} \text{ becomes } \begin{matrix} -I \\ N-I. \\ -I \end{matrix}$$

Now, this nitrogen iodide is a brown powder which, when carefully dried, will remain innocently enough, resting quietly unchanged. If, however, we even so much as tickle this brown substance with a feather, or even if a door in the building in which it lies is rudely slammed, a terrible detonating explosion will occur, and the air will be filled with the stifling, violet-colored fumes of iodine. A quantity of this powder which could be heaped on the surface of a small silver coin would be sufficient to wreck everything in its neighborhood.

Whence this extraordinary energy? The thermodynamics of this and similar reactions are too complicated and mathematical to discuss here, but it is easy to see that the atomic forces at work in the sudden liberation of free nitrogen and iodine atoms, and their instantaneous rearrangement into inert molecules, involve enormous energy effects. Of course, nitrogen iodide is too treacherous a substance to be used as a high explosive, for in the dry condition the merest jar would cause it to detonate. It is obvious, therefore, that it has been the task of the chemist to find ways of locking nitrogen to other elements or groups of elements, with the result that it will be fixed tightly enough so that premature explosion will be avoided, but not so tightly but that it can be exploded by small quantities of more reactive nitrogen compounds made up in the form of percussion caps or detonators.

All modern high explosives are just such chemical combinations of nitrogen as this, and we have, among others, nitroglycerin (dynamite), nitrocellulose (gun-cotton), trinitro-phenol (picric acid), nitrogelatine, trinitro-benzene, trinitro-toluene, etc. Masked under such trade names as Lyddite, Melinite, Turpenite, Cordite, etc., these nitrogen compounds are products of modern chemistry known and used by the armies and navies of the world.

In a later paragraph we shall have occasion to return to the constitutions of these more complicated nitro substitution products. For the present, it will be necessary to inquire into the source and supply of the combined or fixed nitrogen on which modern warfare depends.

On the western coast of South America, in Chile and Peru, there occur vast natural deposits of nitrate of sodium, commonly known as Chile saltpetre. These deposits, with certain exceptions which will be noted later, constitute the world's supply of fixed or combined nitrogen, and in times of peace set the price for all combined nitrogen from whatsoever source derived. In sodium nitrate the nitrogen is linked to oxygen. Treated with sulphuric acid, which is cheap and abundant, sodium nitrate yields nitric acid. Various organic substances treated under certain conditions with nitric acid yield nitro substitution bodies which are used as dyes, while other of these bodies are the high explosives referred to above. But sodium nitrate, for reasons that will now be apparent to the reader, is necessary as a fertilizer to keep up the fertility of the soil and thus make it possible for mankind to work out his destiny through the nitrogen cycle to which he is linked. It is indeed a curious thought that these natural deposits in a more or less remote corner of the world should exercise so great an influence on man and in so diverse a manner: on his life in the growth of the food he eats, and on his death in the production of destructive explosive agents, capable of killing thousands at a single blow.

In spite of the vastness of the Chilean nitrate beds, thoughtful scientific men have for many years given warning of the danger of their exhaustion. In 1898, Sir William Crookes, in his presidential address before the British Association for the Advancement of Science, dwelt in the most earnest manner upon the importance of this problem, and urged upon the attention of chem-

ists and physicists the necessity for developing methods for fixing the inexhaustible supply of nitrogen in the air.

The present annual output of the Chilean fields amounts to about 2,500,000 tons. A recent scientific article [1] on this subject states:

> While there are a few scattered natural deposits other than those in Chile, there is none which has at the present time a chance of competing, most of them being of limited extent and situated in inaccessible regions. In Chile the deposits are easily worked, and even after years of careless mining, with no effort to effect economies, the present cost of producing nitrate is not excessive, varying from $10 to $20 per ton and selling in Liverpool for about $45 per ton. This leaves a profit of from $5 to $10 a ton on the operation, after paying the Government of Chile an export tax of about $12.25 per ton. In the past thirty years this export tax has netted the Chilean Government about $500,000,000. Of the total production of Chile, the United States imports about 600,000 to 700,000 tons per annum, the balance being practically all shipped to European countries. Chile saltpetre has sold for as high as $60 a ton, but since 1909, when the agreement among the producers expired, the price has approximated $45 per ton f. o. b. Liverpool, making a price of from $35 to $40 per ton f. o. b. Chile.

According to the same authority quoted above, 50 per cent. of all the Chile saltpetre imported into the United States is used in the manufacture of explosives, while an additional 25 per cent. is utilized in the arts requiring nitric acid. The balance, or 25 per cent., presumably finds its way to the soil as an intensive nitrogen fertilizer.

Let us now see what statistics will show in regard to the proportion of the two and one-half million tons of nitrate produced in Chile which is yearly imported into this country. The foreign commerce reports of the United States Department of Commerce have made the following figures available:

Nitrate of Soda Imported into the United States for the Twelve Months Ending June——

1913		1914		1915	
Tons	Value	Tons	Value	Tons	Value
589.136	$20,718,968	564,049	$17,950,786	577.122	16,355,701

These figures are interesting and can be interpreted in their relation to world conditions during the years included. They at

[1] "Fixation of Atmospheric Nitrogen," Leland L. Summers, *Trans. Amer. Electrochem. Soc.*, xxvii, 340–341, 1915.

once suggest a number of questions which it will be interesting to note down.

1. Since the United States normally has taken about one-fifth of the world supply of nitrate, and since 75 per cent. of this goes for the manufacture of explosives and nitric acid, what would happen to the United States if it were attacked by a strong naval power which would be able to blockade the western coast of South America and the entrance to the Panama Canal?

2. What reserve supply of fixed nitrogen have we in the United States in case we were called upon to wage a defensive war, and does any one in authority in the United States show any indication of caring at all about this important matter? *

3. Since Germany and Austria have lost command of the sea, where are they getting the enormous supplies of fixed nitrogen necessary for their war against the world?

4. Assuming that England, France, Russia, Italy, and Japan are between them using 2,000,000 tons of Chilean nitrate for the manufacture of explosives, is the quantity adequate to the task they have undertaken?

The answers to these questions, though not treated *seriatim*, will be discussed in the following paragraphs.

In the great iron and steel industries of the world vast quantities of coal have to be partially burned to coke. In this process large quantities of valuable by-products are driven off and can be collected and used for many purposes, both in the peaceful arts and in war. To our everlasting shame be it said that we have for the most part, by the use of the open beehive-shaped coke ovens, allowed these valuable by-products to escape into the air and be lost. One, at least, of the good things that the present war has accomplished is in showing us the folly of such insane waste of valuable material. The substitution of the open type of coke oven by the enclosed by-product recovery oven is now at last going on apace. Our coking coals contain about one per cent. of fixed

* Since this article went to press, announcements have appeared in the daily press, stating that Brigadier-General William M. Crozier, Chief of Ordnance of the United States Army, in his annual report has urged that the nation take steps to be independent of the Chilean beds for the nitrates used in making gunpowder. In addition to this, it is reported that Mr. James B. Dukes announces that his company will turn out four tons daily at once of nitric acid made from nitrogen of the air. If these press reports are correct, answers to some of the questions considered in this paper are already in hand.

nitrogen, and this can all be saved and converted into ammonia or the sulphate of ammonia. It will be remembered that once we have our nitrogen fixed we can use it as fertilizer or convert it by chemical processes into useful products, including high explosives.

Among the coke recovery products we get coal tar, which, in turn, yields such valuable intermediates as benzene, toluene, and aniline, used in the manufacture of an infinite number of dyes, medicines, and explosives. The annual world's production of sulphate of ammonia from gas works and by-product coke ovens now amounts to about 1,250,000 tons, and the Liverpool price approximates that of sodium nitrate, varying from $45 to $60 per ton.

It will be seen, from the above figures, that, while by-product recovery from coke making offers an opportunity to eke out the needed supply of fixed nitrogen, taken by itself this source is insufficient to fill the demand in time of peace, and in time of war and embargo it would be quite inadequate, especially in the United States, where we are comparatively young in the application not only of by-product recovery but also in the chemical processes required to oxidize ammonia to the condition of nitric acid necessary for the manufacture of explosives.

Within the last fifteen years, or since Sir William Crookes sounded his note of warning to the world, chemists have paid especial attention to the problem of the fixation of the inexhaustible supply of nitrogen in the air. There are three lines of attacking this problem, along which substantial success has been attained: *First*, the nitrogen can be made to combine directly with the oxygen of the air to form nitric acid; *second*, the nitrogen can be induced to combine with carbon to form cyanamide (C_2N_2), which can be used directly as a fertilizer or by subsequent treatment changed into ammonia, and hence to nitric acid; and, *third*, nitrogen can be directly linked to waste or by-product hydrogen from other chemical industries to form ammonia. There are also other indirect processes which have been proposed for fixing atmospheric nitrogen, but these need not be discussed here.

It is apparent, from what has been said in an earlier part of this article, that enormous energy is called for in breaking up the linkage $N \equiv N$ and fixing the nitrogen atoms to other atoms, such as oxygen, carbon, and hydrogen. It will not be surpris-

ing, therefore, to learn that the success of such industries must hang, for the most part, on the successful harnessing of great water powers to this end. We have our Niagara and many other great potential water powers in North America; let us inquire, therefore, what we have done in this country toward the solution of this problem with which the future of the human race is so inevitably bound up.

Perhaps it might be permitted to begin this portion of the discussion with the statement that we in the United States have accomplished practically nothing at all along this line. It is a curious fact, often made a subject of comment, that in America have been made nearly all the inventions on which modern warfare depends, all of which, for lack of public interest and financial backing, have passed for their development to foreign countries. This is true of the aëroplane, the dirigible, the submarine, and it is equally true of the nitrogen-fixation processes. In 1902 two American pioneers, Lovejoy and Bradley, established at Niagara Falls their first industrial apparatus for fixing the nitrogen to the oxygen of the air by means of the electric arc and thereby directly producing nitric acid. These pioneers were on the right track, but nobody cared, least of all our government, and so the infant industry died of inanition. I shall now dare to say that it is the development of this pioneer work in the hands of foreign scientists and engineers that made it possible for Germany to challenge a world at arms. Dr. L. H. Baekeland, in the Chandler lecture for 1914, has so excellently summed up the status of nitrogen fixation that no one could improve upon his brief capitulation, nor can Dr. Baekeland's summary be too often printed for the instruction of our countrymen. This eminent authority says:

> The development of some problems of industrial chemistry has enlisted the brilliant collaboration of men of so many different nationalities that the final success could not, with any measure of justice, be ascribed exclusively to one single race or nation; this is best illustrated by the invention of the different methods for the fixation of nitrogen from the air.
>
> This extraordinary achievement, although scarcely a few years old, seems already an ordinary link in the chain of common, current events of our busy life; and yet the facts connected with this recent conquest reveal a modern tale of great deeds of the race—an Epos of Applied Science.
>
> Its story began the day when chemistry taught us how indispensable are the nitrogenous substances for the growth of all living beings.

Generally speaking, the most expensive foodstuffs are precisely those which contain most nitrogen; for the simple reason that there is, and always has been, at some time or another, a shortage of nitrogenous foods in the world. Agriculture furnishes us these proteid- or nitrogen-containing bodies, whether we eat them directly as vegetable products, or indirectly as animals which have assimilated the proteids from plants. It so happens, however, that by our ill-balanced methods of agriculture we take nitrogen from the soil much faster than it is supplied to the soil through natural agencies. We have tried to remedy this discrepancy by enriching the soil with manure or other fertilizers, but this has been found totally insufficient, especially with our methods of intensive culture—our fields want more nitrogen. So agriculture has been looking anxiously around to find new sources of nitrogen fertilizer. For a short time an excellent supply was found in the guano deposit of Peru; but this material was used up so eagerly that the supply lasted only a very few years. In the meantime the ammonium salts recovered from the by-products of the gas-works have come into steady use as nitrogen fertilizer. But, here again, the supply is entirely insufficient, and during the later period our main reliance has been placed on the natural beds of sodium nitrate, which are found in the desert regions of Chile. This has been, of late, our principal source of nitrogen for agriculture, as well as for the many industries which require saltpetre or nitric acid.

In 1898, Sir William Crookes, in his memorable presidential address before the British Association for the Advancement of Science, called our attention to the threatening fact that, at the increasing rate of consumption, the nitrate beds of Chile would be exhausted before the middle of this century. Here was a warning—an alarm—raised to the human race by one of the deepest scientific thinkers of our generation. It meant no more nor less than that before long our race would be confronted with nitrogen starvation. In a given country, all other conditions being equal, the abundance or the lack of nitrogen available for nutrition is a paramount factor in the degree of general welfare or of physical decadence. The less nitrogen there is available as foodstuffs, the nearer the population is to starvation. The great famines in such nitrogen-deficient countries as India and China and Russia are sad examples of nitrogen starvation.

And yet nitrogen, as such, is so abundant in Nature that it constitutes four-fifths of the air we breathe. Every square mile of our atmosphere contains nitrogen enough to satisfy our total present consumption for over half a century. However, this nitrogen is unavailable so long as we do not find means to make it enter into some suitable chemical combination. Moreover, nitrogen was generally considered inactive and inert, because it does not enter readily into chemical combination.

William Crookes's disquieting message of rapidly-approaching nitrogen starvation did not cause much worry to politicians—they seldom look so far ahead into the future. But to the men of science it rang like a reproach to the human race. Here, then, we were in possession of an inexhaustible store of nitrogen in the air, and yet, unless we found some practical means for tying some of it into a suitable chemical combination, we would soon be in a posi-

tion similar to that of a shipwrecked sailor, drifting around on an immense ocean of brine, and yet slowly dying for lack of drinking water.

As a guiding beacon there was, however, that simple experiment, carried out in a little glass tube as far back as 1785 by both Cavendish and Priestley, which showed that if electric sparks were passed through air the oxygen thereof was able to burn some of the nitrogen and to engender nitrous vapors.

This seemingly unimportant laboratory curiosity, so long dormant in the text-books, was made a starting-point by Charles S. Bradley and D. R. Lovejoy, in Niagara Falls, for creating the first industrial apparatus for converting the nitrogen of the air into nitric acid by means of the electric arc.

As early as 1902 they published their results, as well as the details of their apparatus. Although they operated only one full-sized unit, they demonstrated conclusively that nitric acid could thus be produced from the air in unlimited quantities. We shall examine later the reasons why this pioneer enterprise proved a commercial failure; but to these two American inventors belongs, undoubtedly, the credit of having furnished the first answer to the distress call of Sir William Crookes.

In the meantime many other investigators were at work at the same problem, and soon from Norway's abundant waterfalls came the news that Birkeland and Eyde had solved successfully, and on a commercial scale, the same problem by a differently-constructed apparatus. The Germans, too, were working on the same subject, and we heard that Schoenherr, also Pauling, had evolved still other methods, all, however, based on the Cavendish-Priestley principle of oxidation of nitrogen. In Norway alone the artificial saltpetre factories use now, day and night, over 200,000 electrical horse-power, which will soon be doubled; while a further addition is contemplated which will bring the volume of electric current consumed to about 500,000 horsepower. The capital invested at present in these works amounts to $27,000,000.

Frank and Caro, in Germany, succeeded in creating another profitable industrial process, whereby nitrogen could be fixed by carbide of calcium, which converts it into calcium cyanamide, an excellent fertilizer by itself. By the action of steam on a cyanamide, ammonia is produced, or it can be made the starting-point of the manufacture of cyanides, so profusely used for the treatment of gold and silver ores.

Although the synthetic nitrates have found a field of their own, their utilization for fertilizers is smaller than that of the cyanamide; and the latter industry represents to-day an investment of about $30,000,000, with three factories in Germany, two in Norway, two in Sweden, one in France, one in Switzerland, two in Italy, one in Austria, one in Japan, one in Canada, but not any in the United States. The total output of cyanamide is valued at $15,000,000 yearly and employs 200,000 horse-power, and preparations are made at almost every existing plant for further extensions. An English company is contemplating the application of 1,000,000 horse-power to the production of cyanamide and its derivatives, 600,000 of which have been secured in Norway and 400,000 in Iceland.

But still other processes are being developed, based on the fact that certain metals or metalloids can absorb nitrogen, and can thus be converted

into nitrides; the latter can either be used directly as fertilizers or they can be made to produce ammonia under suitable treatment.

The most important of these nitride processes seems to be that of Serpek, who, in his experimental factory at Niedermorschweiler, succeeded in obtaining aluminum nitride in almost theoretical quantities, with the use of an amount of electrical energy eight times less than that needed for the Birkeland-Eyde process and one-half less than for the cyanamide process, the results being calculated for equal weights of "fixed" nitrogen.

A French company has taken up the commercial application of this process which can furnish, besides ammonia, pure alumina for the manufacture of aluminum metal.

An exceptionally ingenious process for the direct synthesis of ammonia, by the direct union of hydrogen with nitrogen, has been developed by Haber in conjunction with the chemists and engineers of the Badische Aniline and Soda Fabrik.

The process has the advantage that it is not, like the other nitrogen-fixation processes, paramountly dependent upon cheap power; for this reason, if for no other, it seems to be destined to a more ready application. The fact that the group of the three German chemical companies which control the process have sold out their former holdings in the Norwegian enterprises to a Norwegian-French group, and are now devoting their energies to the commercial installation of the Haber process, has considerable significance as to expectations for the future.

The question naturally arises: Will there be an overproduction and will these different rival processes not kill each other in slaughtering prices beyond remunerative production?

As to overproduction, we should bear in mind that nitrogen fertilizers are already used at the rate of about $200,000,000 worth a year, and that any decrease in price, and, more particularly better education in farming, will probably lead to an enormously increased consumption. It is worth mentioning here that, in 1825, the first shipload of Chile saltpetre which was sent to Europe could find no buyer, and was finally thrown into the sea as useless material.

Then, again, processes for nitric acid and processes for ammonia, instead of interfering, are supplementary to each other, because the world needs ammonia and ammonium, as well as nitric acid or nitrates.

It should be pointed out, also, that, ultimately, the production of ammonium nitrate may prove the most desirable method so as to minimize freight; for this salt contains much more nitrogen to the ton than is the case with the more bulky calcium-salt under which form synthetic nitrates are now put into the market.

Before leaving this subject, let us examine why Bradley and Lovejoy's efforts came to a standstill where others succeeded.

First of all, the cost of power at Niagara Falls is three to five times higher than in Norway, and, although at the time this was not strictly prohibitive for the manufacture of nitric acid, it was entirely beyond hope for the production of fertilizers. The relatively high cost of power in our country is the reason why the cyanamide enterprise had to locate on the

Canadian side of Niagara Falls, and why, up till now, outside of an experimental plant in the South (a 4000 horse-power installation in North Carolina, using the Pauling process), the whole United States has not a single synthetic-nitrogen fertilizer works.

The yields of the Bradley-Lovejoy apparatus were rather good. They succeeded in converting as much as 2½ per cent. of the air, which is somewhat better than their successors are able to accomplish.

But their units, 12 kilowatts, were very much smaller than the 1000 to 3000 kilowatts now used in Norway; they were also more delicate to handle, all of which made installation and operation considerably more expensive.

However, this was the natural phase through which any pioneer industrial development has to go, and it is more than probable that, in the natural order of events, these imperfections would have been eliminated.

But the killing stroke came when financial support was suddenly withdrawn.

In the successful solution of similar industrial problems the originators in Europe were not only backed by scientifically well-advised bankers, but they were helped to the rapid solution of all the side problems by a group of specially-selected scientific collaborators, as well as by all the resourcefulness of well-established chemical enterprises.

That such conditions are possible in the United States has been demonstrated by the splendid teamwork which led to the development of the modern tungsten lamp in the research laboratories of the General Electric Company, and to the development of the Tesla polyphase motor by the group of engineers of the Westinghouse Company.

True, there are endless subjects of research and development which can be brought to success by efforts of single independent inventors, but there are some problems of applied science which are so vast, so much surrounded with ramifying difficulties, that no one man, nor two men, however exceptional, can furnish either the brains or the money necessary for leading to success within a reasonable time. For such special problems the rapid cooperation of numerous experts and the financial resources of large establishments are indispensable.

So much for the rôle of chemistry in the war in so far as it is affected by the nitrogen-fixation problem. Those who have read thus far will be able to formulate their own answers to the questions set down in an earlier paragraph and will understand how Germany, although cut off from the South America nitrate fields, has been able to assemble and use more high explosives in a shorter time than any one would have believed possible previous to the year of grace (*sic*) 1914.

If we assume that the nations at war have provided themselves with adequate supplies of fixed nitrogen in the condition of nitric acid, let us now return to a more detailed discussion of the materials and methods which modern chemistry uses for the

production of high explosives, without an abundant supply of which modern warfare must immediately come to an end. We have seen in what manner the nations are in fact fighting with fixed nitrogen. Indeed, it may be said that out of the atmosphere comes the power of making war, for there are geological reasons for believing that the nitrogen of the Chile nitrate beds was originally fixed by natural process from atmospheric nitrogen. We must now consider something of the chemistry of the element carbon and the wonderful rôle which it also plays in war.

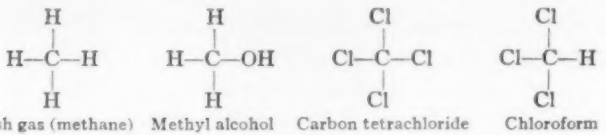
II.

THE RÔLE OF CARBON.

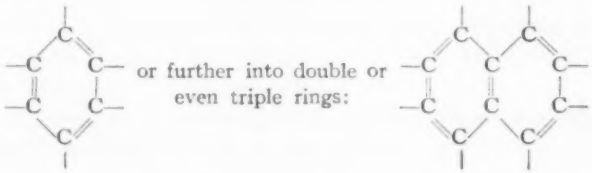
The element carbon, unlike nitrogen, does not appear in Nature in the gaseous form. It is familiar to every one in an impure form as coal, as charcoal and graphite, and in its pure crystallized form as the diamond. Considered as an atom in its chemical sense, it is highly reactive and ever ready to combine with other atoms and groups of atoms to form the endless variety of organic forms which make up the visible universe. The most characteristic attribute of the carbon atom is its power and tendency to link up with other carbon atoms, thus permitting an infinite variety of molecular architecture. It will be necessary to follow this statement a little further, on account of its bearing on the rôle of chemistry in the war.

We have seen that the free atom of nitrogen is called trivalent and is written $N\equiv$. Similarly, the free atom of carbon is known to be quadrivalent and might be written $C\equiv$. As a matter of fact, however, the quadrivalence of the carbon atom is expressed in the following form:

Really the carbon atom with its four bonds is thought of spacially as being at the centre of a pyramid or tetrahedron. For our present purpose, however, we need not confuse ourselves with this conception, but think of it as written above. The point to be understood is that the free affinities of the carbon atom are easily saturated with other atoms or groups of atoms, as, for instance, in the following compounds:



But the most interesting characteristic is the ability of carbon to link up as in —C—C— and —C—C—C— and so on until we reach a string or nucleus of six atoms, when in many cases the string acts as though it were unwieldy and, like a snake with its tail in its mouth, links up into form of a ring known as the benzene ring, and written:

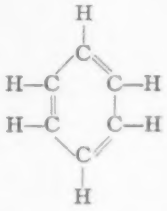


It may appear to the layman that we are involving ourselves pretty deeply in advanced chemistry, but we must be patient, because we are getting close to the secret of modern warfare as it is controlled by high explosives. We are also getting close to the secrets of the dye industry and modern medicinals, which subjects have been much discussed in this country since the outbreak of the war.

Benzene has already been referred to in an earlier paragraph as a by-product of the coke and gas industry. It is a limpid liquid substance which closely resembles gasoline in odor and properties. If cheap enough, it could be used in automobile engines, but its price before the war in this country was about thirty cents a gallon, which was prohibitive of its use for this purpose. It is an important raw material for the manufacture of high explosives, dyes, synthetic medicines, phonographic records, etc. Benzene has the chemical formula C_6H_6, and is to be considered as a ring of six carbon atoms attached as shown above, with one hydrogen atom fixed to each carbon. For the sake of brevity and simplicity, chemists no longer take the trouble to write in the carbon or hydrogen atoms into their ring formulæ, these being assumed, only the significant substituting atoms being placed and written

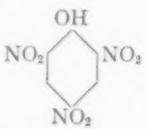
in. Thus, for instance, the benzene or, as the Germans call it, the benzol ring is expressed by writing:

instead of the more cumbersome



Now, suppose by treating benzene with certain chemicals we replace one of the hydrogens by the group of atoms OH, we get

This body is carbolic acid, known to chemists as phenol. It was this substance that we have read in the newspapers Thomas A. Edison needed for making phonograph records after the German supplies ceased, and which he was able to make as soon as the recovered benzol began to be available from the American gas and coke plants. Now, if we start again with phenol and treat it with nitric acid in a special manner, we make trinitro-phenol, or picric acid, an intensely yellow substance which is used as a dye base and is also one of the most deadly of the high explosives. We write the formula of picric acid

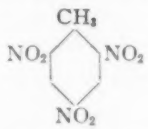


and designate it as a 2, 4, 6 substitution product, for the group or radical NO_2 must fix to just the right points in the carbon ring, or we should not get picric acid, but something else. Perhaps we have now succeeded in getting a glimpse into the wonderful molecular architecture that has been patiently worked out by chemists for the use of man in the arts of peace and war. Untold numbers of tons of picric-acid mixtures under the names of Melinite and Turpenite are being shot off on the European battlefields.

Looking at the graphic representation of the picric-acid molecule written above, it requires but a slight effort of the imagination to picture what takes place when this molecule is suddenly shattered into its elements. Large quantities of hot nitrogen, hydrogen and oxygen atoms are instantly set free, seeking to expand and satisfy their various affinities. The chemical forces of disruption and rearrangement are titanic and, when directed to that end, scatter death and destruction round about.

Picric acid, when dry, melts down quietly at a little above the water-boiling temperature, with little danger of explosion unless it is detonated by something else. It is usually melted down with rosin or some other body which is used to dilute it. It is these other bodies which are partly responsible for the dense clouds of black smoke formed when shells loaded with picric-acid mixtures explode, and which on the European battlefields have earned for them the name of "Jack Johnsons."

Toluene * is a near relative of benzene; it is a liquid slightly less volatile than the latter substance, and is also a by-product of the coke and gas industry. From it we can obtain trinitro-toluene—



This product is also used as a modern high explosive, under the abbreviated name of T. N. T.

The German chemical industries are said to have accumulated vast stores of these and similar by-product nitro-substitution products from their great dye industries. The well-known blue dye, indigo, which used to be extracted from a plant grown in India, is now made synthetically in Germany, and the by-products from the synthesis furnish some of the raw material for the nitro bodies used in explosives. It is said to have taken the patient German chemists over twenty years to work out the synthesis of indigo, but when this was finally accomplished the natural indigo soon disappeared from the markets of the world.

Glycerine is a by-product from the manufacture of soap. By nitration we get nitroglycerin, which, when soaked up in an inert,

* It is interesting to note that the price of benzene has risen from 30 cents to 90 cents a gallon since the war began. Toluene has risen in the same time from 40 cents to $5.00 per gallon.

earthy powder, we call dynamite. Cotton consists mainly of cellulose. When cotton is nitrated, nitro-cellulose or gun-cotton is obtained. When compressed into blocks or other forms, this gun-cotton is a detonating explosive of terribly high power, and is frequently used for loading torpedoes and mines. When made in a different way, however, nitro-cellulose does not detonate but burns rapidly, giving off large quantities of hot expanding gases. When in this form nitro-cellulose is known as "smokeless powder." It is generally not used as a powder, however, but in the form of sticks (cordite) or short cylinders through which holes are bored to facilitate rapid combustion. If cotton can not be obtained, as is probably now the case in Germany, wood-pulp cellulose may be substituted. Gelatine made from slaughter-house refuse or dead horses can in like manner be used in the production of nitro-gelatine. The chemistry of these substances is more complicated than in the cases of nitro-benzene and toluene, so that we need not attempt to go more deeply into the subject in this place. Enough has been said to show the rôle of the chemistry of carbon and nitrogen as this applies to modern warfare.

III.

THE RÔLE OF HYDROGEN.

Hydrogen is the lightest gas known, being about seven times lighter than air, bulk for bulk. The manufacture of caustic alkali on an enormous scale is necessary to every civilized nation for the manufacture of paper, soap, and many other necessities of life. This alkali is in part manufactured by an electric water-power process which yields hydrogen as one of its by-products. At present about 30,000 electrical horse-power are employed in this branch of industry in the United States. In Germany all waste hydrogen is conserved for filling the balloons of Zeppelins and presumably for making synthetic ammonia by the Haber process, as well as for other industrial purposes. In this country practically all the hydrogen is allowed to escape into the air, to seek the outermost reaches of the atmospheric sea. It is probable, however, that the day is not far distant when we, too, will meet the necessity of conserving our hydrogen as well as our other useful industrial wastes.

The story of the development of the Haber process for fix-

ing the nitrogen of the air to by-product hydrogen reads like a fairy tale of science wedded to patience. About twenty-five years ago American students of chemistry at a certain German university were surprised to find their professors carrying on patient researches on methods for oxidizing ammonia to nitric acid. Since in those days nitric acid cost less than ammonia, and as no methods for fixing the nitrogen of the air had even been proposed, so much patient work seemed at best to be premature. The fact is, however, that it was to come about that the great European war was to await the word "Go!" not alone from the statesmen and militarists but also from the distinguished chemist-privy councillors (*Geheimraths*) of the German Empire. At the meeting of the Eighth International Congress of Applied Chemistry held in New York in September, 1912, the German Professor H. A. Bernthsen, in the course of his address,[2] said:

> I propose, however, to-day to deal, from my own direct experience, with the development of the *problem for the synthetical manufacture of ammonia from its elements.* A few years ago the solution of this problem appeared to be absolutely impossible. It has recently been the object of very painstaking investigations by Professor Haber and the chemists of the Badische Anilin- and Soda-Fabrik, and numerous patents have been taken out with reference to the manufacture. Apart from what is already published in this way, however, we have refrained from any other announcements until we were in a position to report something final with reference to the solution of the technical question.
>
> This moment has now arrived, and I am in the agreeable position of being able to inform you that the said problem has now been solved fully on a manufacturing scale, and that the walls of our first factory for synthetic ammonia are already rising above the ground at Appau, near Ludwigshafen-on-Rhine.

So much for the accomplishment of Germany's independence of Chile saltpetre up to 1912. The fact that the contact process for changing synthetic ammonia to nitric acid had already been worked out tells us something of the vision that was in the minds of German scientists at least a quarter of a century ago.

But let us hear further from Professor Bernthsen on some of the difficulties that had to be surmounted before this method of nitrogen fixation was an accomplished fact. He goes on to say:[3]

[2] "Synthetic Ammonia," H. A. Bernthsen, *Trans. Eighth Internat. Cong. Applied Chem.*, vol. xxviii, pp. 185 and 186.

[3] *Ibid.*, pp. 193–194, 199–200.

The problems to be solved were quite new and strange and demanded the mastery of very unusual difficulties. Although working with compressed gases under pressure at very low temperatures was already known in the industry, the problem here was the totally different one of constructing apparatus which should be large enough and at the same time able to withstand the high pressure with temperatures not far from a red heat. How well founded were the doubts as to the possibility of a solution of this task can be gathered from the instance of the wrought-iron autoclaves commonly used in the color industry. Here, in spite of a very low range of temperature of at most 280° C., only pressures of from 50 to 100 atmospheres at the utmost come into consideration. But above 400° C. iron loses its solidity to a very extraordinary degree.

There is, further, the circumstance that the metals which come into consideration for the construction of the apparatus, and especially iron, are chemically attacked above certain temperatures by the gas mixture under pressure. Although the formation of iron nitride from iron and ammonia, which could have been expected according to the work of Fremy and others, can be avoided, yet it is found, for example, that steel containing carbon loses its carbon at the temperatures in question, owing to the action of the hydrogen, so that its capability of withstanding pressure is reduced to a minimum. It was further found, when using iron itself, that it is completely changed in its qualities, chiefly by taking up hydrogen. Again, at such high temperatures iron is pervious to quite a remarkable degree to hydrogen under high pressures. The question of materials for the apparatus, therefore, raised at once considerable difficulties, but at length these were more than overcome by suitable construction, details of which, I am sure, you will not expect from me to-day. The danger of serious explosions or of great, sudden flames of hydrogen, if the apparatus happens to become defective, can be guarded against by setting it up in bomb-proof chambers.

Great care must naturally be taken that oxygen or air does not get into the apparatus or the piping, for at the high pressure obtaining the explosion range is reached with merely a slight percentage of oxygen. Special devices are used to watch over this content of oxygen, and immediately a definite percentage is touched the alarm is automatically raised. Besides this, the proper constitution of the gas mixture in circulation is controlled by analysis from time to time.

The *ammonia* can be *removed* either by being drawn directly from the apparatus in liquid form, or an absorption agent can be suitably introduced into the apparatus. The simplest absorbent, water, has been found to be suited for this purpose; under the pressure used a concentrated solution of ammonia is secured. Any ammonia that may remain in the gas after the bulk has been removed by one or other of these methods can be further removed by special chemical means, if it is not preferred simply to leave it in the circulating gases.

. . . . . .

The question has not yet been touched upon in the foregoing, how the elements nitrogen and hydrogen which are requisite for the new ammonia process can best be produced on a technical scale. Theoretically, the task

would be unusually simple. If you remember that the terrestrial atmosphere, acording to the studies of A. Wagener and others, consists of practically pure hydrogen at a height of about 120 kilometres—indeed, at a height of about 70 kilometres consists of almost exactly one volume of nitrogen and three volumes of hydrogen, besides a trace (about one-half per cent.) of oxygen—you will understand that all the conditions were given for an ammonia factory according to Jules Verne; for it would then merely be necessary to suck down the gases from the higher strata of the atmosphere by a sufficiently long pipe line.

For us, poor mortals, matters are not so ideally simple, for, as the poet says,

"Hart im Raume stossen sich die Sachen."

Fortunately, however, there is no great difficulty in separating nitrogen from the air, either by physical means, according to Linde's process, or chemically, by removing the oxygen with glowing copper, burning hydrogen, or the like. And for the preparation of hydrogen in recent times a great deal of useful work has been done, too, owing to the extensive growth of its field of application. In certain works it is at disposal in large quantities as a by-product of the electrolysis of common salt. Besides this, it can be produced, for example, by passing steam over red-hot iron, or from water-gas, for instance, by separating its constituents, hydrogen and carbon monoxide, by cooling to a very low temperature. All the methods of preparation which come into consideration we have, of course, minutely examined; owing to the comparatively trifling differences in the cost of production various methods can be employed. At all events, both elements, nitrogen and hydrogen, are at the disposal of the new industry to any extent and sufficiently cheap.

As the production of these elements is not confined to the presence of cheap water-power, all those countries where the manufacture of calcium nitrate, owing to the want of such power, is not practicable, as, for instance, in Germany, are now in a position to profit by the new industry.

The above quoted matter makes interesting reading in the light of the history of the past three years. The synthesis of ammonia by the Haber process takes place by heating a mixture of hydrogen and nitrogen gas under enormous pressures in great alloy-steel bombs buried in bomb-proof cellars, and then rapidly withdrawing and cooling the synthetic ammonia ($N{-}H$, H, H) which is formed. But this is not all of the story.

Even when all these titanic arrangements have been made, the synthesis of ammonia does not take place unless a *catalyst* is present.

Is this fairy tale of science getting too deep for ordinary comprehension, and is it time, as Lewis Carroll's Walrus said,

to talk of other things, such as ships and shoes and sealing-wax and cabbages and kings?

But, as a matter of fact, could a world-war be declared or waged without every one of those four things or the things they stand for that the Walrus wanted to talk about?

And now we are also to learn that a world-war can not be waged without a catalyst! And what on earth is a catalyst?

Those who wish to follow this monster to its lair must be referred to the dictionaries and encyclopædias, but, after all, it is not so frightful as it sounds. In a few words, the meaning is this: A number of important and difficult chemical reactions will not take place, or only very slowly, unless some substance is present in such a manner that it can come into contact with the reacting bodies and thus act the rôle of a go-between promoter or introducer. Such a substance is not changed or necessarily wasted while the action is going on, but acts merely by contact.

Chemists have called this kind of action catalysis. Some one has said that the industrial development of a nation can be measured by the quantity of sulphuric acid that it produces, and it is interesting to note, in passing, that catalysts or contact agents have in modern times revolutionized the production of this most important substance. Catalysts consist usually of some metal or compound of a metal in finely-powdered or subdivided form. As they are not used up or wasted in doing their work, and only comparatively small quantities are needed, the rarest and most expensive metals, such, for instance, as platinum, can be used even in very large-scale operations. Haber found that such rare and unusual metals as molybdenum and tungsten made excellent catalysts for promoting the synthesis of ammonia. But here we have to refer to one of the most curious facts that has been developed by modern chemical research. It has been found that these catalysts can be poisoned by certain things very much in the same way as though they were living cells. That is to say, there are substances which hinder or prevent or kill the activity of these catalysts, although the contact mass does not suffer a noticeable chemical change, envelopment, or destruction. For instance, traces of arsenic mixed with the sulphur from which sulphuric acid is made will poison the platinum catalyzer, whereas it has been found that, on the contrary, the presence of arsenic will act fa-

vorably (or medicinally, as it were) when iron oxide is used as a catalyst.

We are now prepared to hear Professor Bernthsen [4] on this subject and to admire and marvel at the persistence and painstaking efforts made by modern science to overcome the obstacles with which Nature seems to surround her most profound secrets:

It has now been ascertained that some of the poisons in the synthesis of ammonia are of quite a different nature from those of the sulphuric acid process; they are, for instance, sulphur, selenium, tellurium, phosphorus, arsenic, boron, or the compounds of these elements, such as sulphuretted hydrogen, arsenic hydride, phosphorus hydride, as also many carbon compounds and certain metals of low melting-point which can readily be reduced by hydrogen from their compounds; for example, lead, bismuth, and tin, which do not act catalytically. Oxygen-sulphur compounds, such as SO_2, which acts directly and smoothly in the sulphuric-acid catalysis, are very poisonous. Extremely minute quantities of these bodies, which are almost always present even in the purest commercial products or in the so-called pure gases, suffice to render the catalysts absolutely inactive, or at least to diminish their action very seriously. Thus iron, for example, prepared from ordinary iron oxide with a content of one per thousand of sodium sulphate, is, as a rule, inactive. Iron containing one-tenth per cent. of sulphur is generally quite useless, and even with one-hundredth per cent. is of very little use, although in appearance and when examined with the ordinary physical and chemical methods no difference at all can be detected as compared with pure iron.

The recognition of these facts gave rise to two problems:

(*a*) The preparation of contact masses free from poison, or the removal of such poisons from them; and

(*b*) Freeing the gases to be acted on catalytically from all contact poisons.

In order to free the contact bodies from these harmful substances, the ordinary methods for removing them can, of course, be applied. The contact action can also be improved by heating contact metals which are inactive or of little use, owing to the presence of contact poisons, in the presence of oxygen or of bodies yielding oxygen. Or the metals can be heated, for instance, in the presence of oxygen, with the addition of suitable compounds, such as bases, and the resulting products reduced. These operations can be repeated if necessary. If more of such a body as mentioned is added than is necessary, it may act not merely by removing the poisons, but promote the yield, as I have already described to you.

On the other hand, it is necessary, as I remarked, to take the greatest care that nitrogen and hydrogen are free or freed completely from all contact poisons. Thus a trace of sulphur, one part per million, in the gas mixture can under certain conditions be injurious, so that even electrolytically-prepared hydrogen must generally be further specially purified. The minute purification of the gases is even more important when hydrogen prepared, for example, from the water gas is used. The impurities, too, taken up from iron

[4] "Synthetic Ammonia," H. A. Bernthsen, *Trans. Eighth Internat. Cong. Applied Chem.*, vol. xxviii. pp. 197–199.

piping play sometimes an important part, and impurities which get into the gases during the compression, such as machine oil, often have a harmful effect.

The best method of removing impurities from the gas mixture depends, in turn, on the nature of these impurities and consists, for instance, according to the case, in filtering, washing, conducting over solid absorption agents, and so on. One good method is to bring the gases into contact with the material of which the contact mass is prepared at a raised temperature, before passing them over the actual catalyst. The material takes up the impurities, and must, of course, be renewed from time to time. The negative results of earlier investigators in the formation of ammonia when using base contact metals (Wright, Ramsay and Young, and, more recently again, 1911, Neogi and Adhicary), according to which nitrogen and hydrogen do not combine in the presence of iron, are, in my opinion, probably due, for the most part at least, to the use of metals or gases not free from contact poison. That previous inquirers had not the remotest idea that sulphur in the contact metal could be injurious is evident from the fact that they passed the gases without hesitation through concentrated sulphuric acid in order to dry them. The sulphuric acid thus taken up and the sulphur dioxide often contained in it can poison even the best catalyst very speedily and render it unfit for use. Or the contact metals were sometimes prepared directly from the sulphates, although a metal sufficiently free from sulphur can scarcely be obtained by this method.

A painstaking study, for which we are indebted principally to Dr. A. Mittasch and which involved literally many thousands of experiments, has afforded an insight into the importance of substances of the most varied nature as promoters and poisons, and thus a sure foundation has been prepared for a reliable continuous manufacture with a good yield of ammonia.

This is a wonderful story that has been here set forth, and should show very clearly that modern warfare depends not alone upon the work of a general military and naval staff or upon the drilling and marshalling of millions, but, first and foremost, upon the systematic and painstaking researches of scientists, who, to use a homely expression, might be said to be twisting reluctant Nature's tail in the effort to make her march in the desired path.

IV.

THE RÔLE OF THE HALOGENS.

No description of the rôle of chemistry in modern warfare would be quite complete without some reference to the poisonous gases and flames with which modern armies seek to ruin and devastate one another. A vast amount of terrifying descriptive matter has appeared in the press accounts of the great war, but very little accurate scientific information on this awful contribution of chemistry has as yet been made available.

We may safely discount as untrue the extraordinary stories of soldiers asphyxiated and left standing or sitting rigidly in the positions in which they were overcome. It is possible that bombs have been hurled that set free prussic acid or the deadly cyanogen gas (CN), another form of fixed nitrogen. It is more probable, however, that the most deadly effects have been produced by the use of a group of very active chemical elements known as the halogens. By the name of "halogens," meaning salt-formers, chemists distinguish the group of closely-allied elements, chlorine, bromine, and iodine. At ordinary temperatures and pressure, chlorine is a greenish-colored gas, bromine is a dark-red fuming liquid, and iodine is a beautiful violet-colored solid. At temperatures slightly above the ordinary bromine and iodine turn to heavy red and violet vapors. Chlorine is found in Nature fixed to the element sodium in common salt (sodium chloride). Sodium and other bromides are found accompanying common salt, while the principal source of iodine is seaweed, as marine growths have the power of collecting and concentrating iodides from salt water. It is characteristic of the halogens that they are among the most active chemical agents known. When in a free state they seem anxious to combine with anything they can take hold of, and the mucous membrane of the human throat, lungs, and eyes is peculiarly sensitive to their corrosive action. Chlorine gas, the most active of the family, is obtained in enormous quantities in the same way that hydrogen is, as a by-product from the electric process of manufacturing caustic alkali from common salt.

In the arts of peace chlorine has an important use as a bleaching agent in the paper and other industries. When compressed into steel cylinders, it can be liquefied and thus shipped from one point to another, or it can be absorbed in lime to form the well-known chloride of lime or bleaching powder. In war liquefied chlorine contained in steel shells can be burst among the enemy, and when the conditions are favorable terrible effects can thus be produced.

Bromine has never found any extended use in the peaceful arts, in spite of the fact that it has been stated that the German Government has been for a number of years offering a prize for the discovery of a practical use for it. Bromine is also a by-product material which has been largely allowed to escape in this

country, but which in Germany has been saved in increasing quantities for years.* In war bromine is even more terrible than chlorine, for it possesses the property of especially attacking the eyes, even producing blindness in large doses. If it comes in contact with the skin, it produces horrible burns which are slow to heal. When chlorine gas is allowed to come in contact with bromine under certain controlled conditions, they combine together to form a limpid fuming liquid, known as chloride of bromine, which combines the properties of both elements. It is said that this awful substance is the material that the warring nations have been hurling at each other in shells, bombs, and hand-grenades, although exact facts regarding these dreadful practices will probably not be available until after the war is over.

The rôle of iodine in the war is probably of a more kindly nature; it is not nearly so active an agent as the other two members of its family, and when dissolved in alcohol to make a tincture it has saved many lives on the battlefield when used as an antiseptic on open wounds

Some of the newspaper accounts have described gas bombs which exploded with dense violet fumes. If true, this points to the use of iodine also for this destructive purpose, but it is not probable that such a use is common, owing to the higher cost, greater scarcity, and limited activity of iodine as compared with the other halogens.

Much has also been written in regard to the masks or breathers

* Bromine.—Both technical and U. S. P. descriptions of this commodity continue in scanty supply and strongly held at a minimum of $5 by leading manufacturers, while maintained at $6 and even at $6.50 by second hands. Reports to the effect that the recent sharp uplift of prices for this article has been due to the operations of a syndicate of makers in Michigan, Ohio, Virginia, and West Virginia are not credited by those in a position to know, as it is obvious that the growing shortage, due to recent heavy sales on contracts to European users, is alone responsible for this upward movement of prices. Seemingly this extensive export movement of bromine can not be forbidden by the United States Government authorities or virtually prohibited by a high export tax, without enactment to this effect by Congress. Efforts to prevent further heavy shipments of this commodity to foreign countries have recently been made in vain by manufacturers of bromides who complained of this export movement to the Secretary of Commerce only to be referred to a special investigator in New York city, who informed him that the government was powerless to interfere with this business.—*Oil, Paint and Drug Reporter*, New York, Dec. 20, 1915, p. 44.

resorted to for protection from these dangerous gases. There are a number of chemical substances which are absorbents of chlorine and bromine and with which they can combine or fix themselves. Such chemicals spread between layers of fabric or liquids in which fabric masks can be soaked probably furnish such means as are available for protection.

CONCLUSION.

Besides the rôle of chemistry in war, the allied art of metallurgy plays an important part. New steels and alloys have to be devised, tested, and finally manufactured, suitable for the varied needs of war. Aëroplanes, dirigibles, and submarines all require materials with special physical characteristics. It is said that the metallurgists of Germany had to devise a new steel alloy before the Haber process for fixing nitrogen could be successfully worked on the large scale of operation. Space here does not permit of a description of these special metals, but perhaps enough has been said to give the reader a general purview of the rôle of chemistry in war.

Although it has been shown that chemistry is the handmaiden of war, and that this last great struggle is indeed a chemists' war, as Dr. L. H. Baekeland has recently so happily phrased it:[5]

> Do not imagine that this is the first chemical war. The art of killing and robbing each other became chemical the day gunpowder was invented; at that time, however, the existing knowledge of chemistry was just of pinhead size. Napoleon knew very well how to use adroitly exact knowledge and chemistry for furthering his insatiable ambition to dominate the world; so he surrounded himself with the most able chemical advisers and scientists. Ever since then science, technology, and chemistry in particular have played a rôle of increasing importance in the armament of nations. . . .
>
> Do not reproach chemistry with the fact that nitro-cellulose, of which the first application was to heal wounds and to advance the art of photography, was stolen away from these ultra-pacific purposes for making smokeless powder and for loading torpedoes. Do not curse the chemist when phenol, which revolutionized surgery, turned from a blessing to humanity into a fearful explosive, after it had been discovered that nitration changes it into picric acid.
>
> Let us hope, in the meantime, that war carried to its modern logical gruesomeness, shorn of all its false glamour, deceptive picturesqueness, and rhetorical bombast, exposed in all the nakedness of its nasty horrors, may hurry along the day when we shall be compelled to accept means for avoiding its repetition.

[5] "Chemical Industry," address by Dr. L. H. Baekeland before the American Chemical Society, Seattle, Wash., August 31, 1915.

Americans, North or South, probably without exception will join eagerly in the hope thus eloquently expressed, but in the meantime and under present conditions a strong, rich nation can no more exist without adequate means of self-defence than a modern city could exist without a trained police force and fire department. This paper has shown that fixed nitrogen is the first and most important element of national defence. The paper will have well served the author's purpose in preparing it if it should succeed even to a slight extent in calling attention to the necessity for purchasing and storing at a central point an adequate supply of Chilean nitrate. As an alternative, arrangements should be made which would have the effect of inducing capital to exploit in this country the fixation of atmospheric nitrogen. The fact that fixed nitrogen will become an increasingly important factor in the production of food simply means that, come peace or war, foresighted preparation will not under any circumstances be unprofitable or in vain.

The Flow of Air through Thin-plate Orifices. E. O. HICKSTEIN. (*Proceedings of the American Society of Mechanical Engineers,* December 7 to 10, 1915.)—That the problem of measuring large quantities of natural gas has not yet been solved will be conceded by most engineers familiar with the situation. During the past five years the rapidly-diminishing supply and consequent rise in price of this commodity have stimulated investigators to a closer study of its accurate measurement. Among the more important types of meters now used in measuring natural gas in large quantities may be mentioned proportional meters, pitot tubes, orifice meters, Venturi meters, rotary meters (on the anemometer principle), and electric (or calorimetric) meters. Due to the development of satisfactory differential gauges some years ago for recording small differences between two high static pressures, the last few years have seen a great increase in the number of pitot-tube and orifice-meter installations.

The orifice meter consists of a calibrated orifice disk in a pipe line with pressure line connections running to two indicating or recording gauges; one gauge is for measuring the static pressure of the flowing gas, the other the drop in pressure across the orifice. General formulæ for the flow through such orifices have been deduced and extensive tests made to determine the coefficients of discharge. About fifty orifice meters have been installed and are now in operation, and it is predicted that with further study and experimenting the orifice meter will rank among the most reliable methods of measuring natural gas in large quantities.

ON THE SINGLE-LINE SPECTRA OF MAGNESIUM AND OTHER METALS AND THEIR IONIZING POTENTIALS.*

BY

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I. INTRODUCTION.

It has been shown by Frank and Hertz[1] that when heated mercury vapor is traversed by electrons possessing kinetic energy slightly above that acquired in a fall of potential of 4.9 volts the vapor is stimulated to the emission of the single spectral line $\lambda = 2536.72$ Å. U. It has also been shown by McLennan and Henderson[2] that a spectrum consisting of this single line only can be obtained from mercury vapor when it is bombarded by electrons possessing energy corresponding to any fall of potential within a range beginning at about 5 volts and extending up to slightly over 10 volts. The investigation has also been extended by McLennan and Henderson to include a study of the radiation emitted by zinc and cadmium vapors when traversed by electrons. With these vapors they have found that single-line spectra can be obtained when the electrons traversing these vapors possess kinetic energy lying within a limited and clearly-defined range, which has not been fully investigated as yet, but which corresponds roughly to potential differences lying between 4 volts and 13.6 volts. With zinc vapor the single-line spectrum consists of light of wave-length $\lambda = 3075.99$ Å. U., and with cadmium vapor of light of wave-length $\lambda = 3260.17$ Å. U. It should also be pointed out here that the lines $\lambda = 2536.72$ Å. U., $\lambda = 3075.99$ Å. U., and $\lambda = 3260.17$ Å. U. are respectively the first members of Paschen's[2a] combination series $\nu = 2$, $p_2 - m$, S, for the elements, mercury, zinc, and cadmium.

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* Presented at the meeting of the Section of Physics and Chemistry held Thursday evening, November 11, 1915.

[1] *Verh. d. Deutsch. Phys. Ges.*, vol. 11, p. 512 (1914).

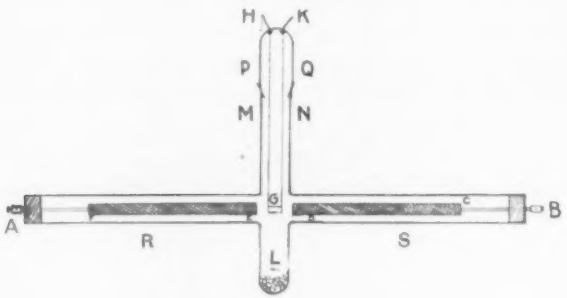
[2] *Proc. Roy. Soc. A.*, vol. 91, p. 485 (1915).

[2a] Paschen, *Ann. der Phys.*, No. 10, p. 869, 1911.

II. THE SINGLE-LINE SPECTRUM OF MAGNESIUM.

Since the publication of the results described above, the radiation from magnesium vapor traversed by electrons has been investigated by the writer, and it has been found with this element, too, that a single-line spectrum can be obtained if the electrons bombarding the vapor possess energy lying within a certain range whose limits also have not as yet been definitely determined, but which covers a portion at least of the ranges mentioned above for mercury, zinc, and cadmium. In carrying out these experiments the apparatus used and the procedure followed were precisely the same as those described in the paper by McLennan and Henderson. The form of arc used is that shown in Fig. 1. The apparatus consisted of a tube of fused quartz possessing

FIG. 1.

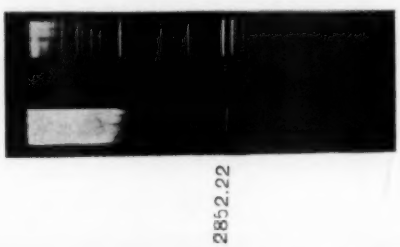


three arms, R, S, and MN, and a receptacle L. Some of the metal to be used in the arc was placed in the receptacle L, and two rods of the same metal, FE and DC, were attached to two wires, and these latter were in turn fastened to two brass plugs, A and B, which were sealed into the tubes R and S with mastic wax. A small piece of sheet platinum was attached to two wires which constituted the heating circuit, and these were sealed with platinum wire into a glass tube PQ at H and K. The open end of the glass tube PQ was ground so as to fit exactly into the end of the quartz tube MN, as shown in the diagram. The arms MN, R, and S were each about 40 cm. long and it was found with this length that when the receptacle L was strongly heated with a Bunsen burner the wax joints at A and B and the ground one at the end of the tube MN remained quite cool. In the experiments the plate G was coated with a thin layer of either cal-

cium oxide or barium oxide. When the tube was in operation the terminals of an auxiliary heating circuit were attached at H and K, B and K were joined by a wire, and the arcing voltage was applied between B and A, the latter being the positive terminal. With this arrangement G and D constituted a double cathode. The tube was highly exhausted with a Gaede mercury pump through a glass tube which was sealed into an opening in the brass end-piece at A.

In taking photographs the plate G was brought to incandescence by means of the auxiliary heating current, the metal in L was strongly heated with the flame of a Bunsen burner so as to keep the plate G surrounded with the vapor of the metal, and the collimator of a small spectrograph with a quartz train was directed at the incandescent plate G. A short tube of asbestos was

FIG. 2.



attached to the quartz tube directly in front of this plate so that the radiation from the arc passed through it to the slit of the spectroscope. This arrangement was found necessary in order to cut off the radiation from the Bunsen flame itself. It should be noted that in studying the radiation from mercury vapor the electrodes CD and FE were simply stout iron wires.

With the arrangement just described it was found that when the direct-current, 110-volt circuit, with suitable resistances in series, was applied to the terminals A and B, and the plate G brought to incandescence, strong arcs could be maintained for hours with mercury, zinc, or cadmium. With the 220-volt circuit applied the arcs of all three metals could be made most intense, and could also be maintained for long periods. With the 220-volt circuit it was found that, when the arc was once struck, it could be easily maintained for a considerable time without the continued use

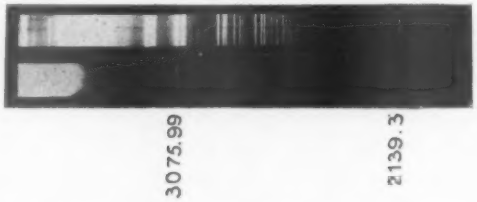
of the oxy-cathode G. With low voltages, however, it was always necessary to maintain the plate G at incandescence in order to keep the arc established.

With magnesium the arcs could be maintained for short periods only and it was difficult to keep the vapor of the metal from condensing on the walls of the tube. The single-line spectrum of this

FIG. 3.

element consists of light of wave-length $\lambda = 2852.22$ Å. U. The ordinary spark spectrum of magnesium in air is shown in the upper row in Fig. 2, and the single-line spectrum of the vapor of the metal in the second row of the same figure. The latter was obtained with a three-hour exposure, and the electrons which stimulated the vapor to the emission of this radiation acquired their kinetic energy

FIG. 4.



with an arcing potential of 8.2 volts applied between the Wehnelt cathode and the positive terminal.

The single-line spectrum for mercury vapor which is shown in Fig. 3, at $\lambda = 2536.72$ Å. U., was obtained with an arcing potential difference of 9 volts with an exposure of two hours and a half. This single-line spectrum was also obtained with a potential fall of 5 volts, but it was only just visible on the plate with a five-hour exposure. With 3 volts and a five-hour exposure the line was not obtained. The line $\lambda = 3075.99$ Å. U., shown in

the lower spectrogram of Fig. 4, was obtained with zinc vapor and an arcing potential of 10.5 volts with an exposure of three hours, and the line $\lambda = 3260.17$ Å. U., shown in the lower spectro-

FIG. 5.

gram of Fig. 5, was obtained with cadmium vapor with an arcing potential difference of 13.6 volts. With an arcing potential of 3.4 volts and a three-hour exposure no trace of the line was obtained with this element.

III. THE ABSORPTION SPECTRA OF MAGNESIUM AND OTHER METALLIC VAPORS.

In a paper recently published by McLennan and Edwards[3] it has been shown that in the absorption spectrum of mercury there is an absorption band at $\lambda = 2536.72$ Å. U., and one at $\lambda = 1849.6$ Å. U. With this vapor it has been found that there is also a complex band obtainable at $\lambda = 2338$ Å. U., when high vapor densities are used. With zinc and cadmium vapors it has been shown by the same writers that the absorption spectra consist of but two absorption bands. With zinc vapor these are at $\lambda = 3075.99$ Å. U., and at $\lambda = 2139.3$ Å. U., and with cadmium vapor they are at $\lambda = 3260.17$ Å. U., and $\lambda = 2288.79$ Å. U. As pointed out above, the lines $\lambda = 2536.72$ Å. U., $\lambda = 3075.99$ Å. U., and $\lambda = 3260.17$ Å. U. are the first members of Paschen's combination series for the three elements represented by $\nu = 2$, $p_2 - m$, S, and they are therefore the lines of this series corresponding to the value $m = 1.5$. Again, it will be seen, by referring to

[3] McLennan and Edwards, *Proc. Roy. Soc. of Canada*, 1915; *Phil. Mag.*, November, 1915.

Paschen's[4] paper, that the lines $\lambda = 1849.6$ Å. U., $\lambda = 2139.13$ Å. U., and $\lambda = 2288.79$ Å. U. are the first members of the series $\nu = 1.5$, $S - m$, P, predicted by Paschen and later identified in part by Wolff[5] for the three elements mercury, zinc, and cadmium.

It does not appear, from communications which have come to the notice of the writer, that a series corresponding to $\nu = 1.5$, $S - m$, P has as yet been identified in the spectrum of magnesium, but if we assume that the line $\lambda = 2852.22$ Å. U. is the first line in the combination series $\nu = 2$, $p_2 - m$, S for this element, sufficient information is given in a paper by Dunz[6] to calculate the first and the last member of the series $\nu = 1.5$, $S - m$, P for this metal. In the paper by Dunz referred to, the frequency of $\nu = 2$, p_2 in the magnesium spectrum is given as 39,793.21. If we take the frequency of the line $\lambda = 2852.22$ Å. U. to be 35,050.45, it follows that the frequency $\nu = 1.5$, S is equal to 74,843.66. This will then be the frequency of the last line of the series spectrum of magnesium given by $\nu = 1.5$, $S - m$, P. Again, in the paper by Dunz the frequency $\nu = 2$, P is given as 26,612.7, and from this it follows that the frequency of the first line in the series $\nu = 1.5$, $S - m$, P (*i.e.*, $\nu = 1.5$, $S - 2$, P) is 48,230.96. This, it will be seen, is the frequency of the line $\lambda = 2073.36$ Å. U. If then the vapor of magnesium were to act, as regards absorption, in a manner analogous to the vapors of mercury, zinc, and cadmium, the absorption spectrum of magnesium vapor should contain absorption bands at $\lambda = 2852.22$ Å. U. and at $\lambda = 2073.36$ Å. U. On looking up the literature on the subject it was found that Wood and Guthrie[7] and Eder and Valenta[8] had already shown that there is an absorption band in this spectrum at $\lambda = 2852.22$ Å. U., but, as no one seemed to have found any band at $\lambda = 2073.36$ Å. U., some experiments were made to see if it really existed. The experiments confirmed its existence, and a reproduction of one of

[4] Paschen, *loc. cit.*

[5] Wolff, *Ann. der Phys.*, 1913, vol. xlii, p. 525.

[6] Dunz, "Bearbeitung unserer Kenntnisse von den Serien," Inaug. Diss., Tübingen, 1911.

[7] Wood and Guthrie, *Astrophys. Jour.*, vol. xxix, No. 1, p. 211 (1909).

[8] Eder and Valenta, "Atlas Typischer Spectren," Table xxvii.

the photographs taken is shown in Fig. 6. The upper portion of this figure was taken with the light from the spark between magnesium terminals in air, and the lower one with the same light after it had traversed an evacuated clear fused quartz tube containing heated non-luminous magnesium vapor. As the reproduction shows, absorption occurred at $\lambda = 2852.22$ Å. U. and at $\lambda = 2073.36$ Å. U., as well. In addition, a narrow absorption band appears at $\lambda = 2536.72$ Å. U. This band also appeared in the experiments of McLennan and Edwards referred to above in the absorption spectrum of zinc and cadmium vapors, and it was no doubt due to a trace of mercury vapor which may have come from mercury originally present as an impurity in the metals or from mercury which got into the absorption tubes containing the vapors

FIG. 6.

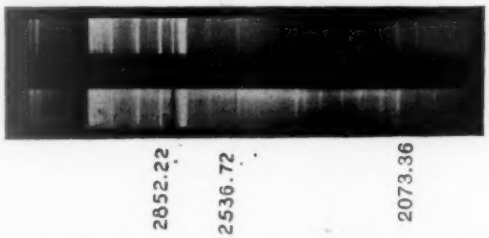


FIG. 7.

when these tubes were exhausted by the Gaede mercury pump. From this result it will be seen that the absorption spectrum of magnesium vapor is exactly analogous to the absorption spectra of mercury, zinc, and cadmium. The analogy, moreover, between the absorption spectrum of magnesium and that of mercury is more perfect than would appear from the above considerations, for the absorption band at $\lambda = 2536.72$ Å. U., in the absorption spectrum of mercury vapor, comes out with small vapor densities as two narrow absorption bands whose wave-lengths have been given by R. W. Wood [9] as $\lambda = 2536$ Å. U. and $\lambda = 2539$ Å. U. The absorption band at $\lambda = 2852.22$ Å. U., in the absorption spectrum of magnesium vapor, has also been found to consist of two narrow, sharply-defined bands very close together. These are shown in the reproduction in Fig. 7, which was obtained by

[9] R. W. Wood, *Astrophys. Jour.*, vol. xxvi, No. 1, p. 41.

greatly enlarging a negative of the band in Fig. 6 at $\lambda = 2852.22$ Å. U. The bands at $\lambda = 3075.99$ Å. U. and $\lambda = 3260.17$ Å. U., in the absorption spectra of zinc and cadmium vapors, have not as yet been resolved into analogous doublets.

IV. THE SINGLE-LINE AND ABSORPTION SPECTRA OF CALCIUM, STRONTIUM, AND BARIUM VAPORS.

The attention of the writer was recently directed to papers by Charles De Watteville [10] on "Flame Spectra." In these papers the author has pointed out that the spectrum of the radiation from the cone of a flame fed by the spray of salt solutions of a number of elements consists in some cases of but a single strong line, and in others of a single strong line accompanied by a number of very much fainter ones.

These strong lines for the different metals are:

Magnesium	2852.22	Å. U.
Mercury	2536.72	" "
Zinc	3075.99	" "
Cadmium	3260.17	" "
Calcium	4226.91	" "
Strontium	4607.52	" "
Barium	5535.69	" "

De Watteville in his papers points out that these metals all belong to Mendelejeff's second group, and he also presents a number of considerations which led him to conclude that these lines are corresponding ones in the spectra of these seven metals. If we accept this conclusion it follows, from what goes before, that calcium, strontium, and barium vapors should emit single-line spectra of the wave-lengths just mentioned if bombarded by electrons possessing the requisite amount of energy. It also follows that absorption bands should appear in the absorption spectra of the vapors of these metals at the respective wave-lengths given above. The only information regarding the absorption spectra of these metals which the writer has been able to find is contained in the "Atlas of Spectra," by Eder and Valenta.[11] In Table XXII of this atlas a spectrogram is given of the arc spectrum of calcium which shows a strong reversal band

[10] De Watteville, *Phil. Trans. Roy. Soc.*, Series A, vol. 204, pp. 139–168 (1904), and C. R. No. 142, 1906.

[11] Eder and Valenta, *loc. cit.*

at $\lambda = 4226.91$ Å. U., but it also shows in addition faint reversals at $\lambda = 3934$ Å. U., $\lambda = 3936$ Å. U., $\lambda = 4440$ Å. U., and $\lambda = 4460$ Å. U. In the same table a spectrogram of the arc spectrum of strontium bromide also shows reversals at $\lambda = 4607.52$ Å. U. and $\lambda = 4078$ Å. U., and in Table XXIII a spectrogram of the arc spectrum of barium bromide shows reversals at $\lambda = 5535.69$ Å. U. and $\lambda = 4554$ Å. U. No direct investigation of the absorption spectrum of the vapors of these metals appears to have been made as yet, but experiments are now being made by the writer, and it is expected that some information on this subject will be soon forthcoming.

If the line spectra of calcium, strontium, and barium be analogous to those of mercury, zinc, cadmium, and magnesium, then the spectra of the first-named metals should each contain a series given by $\nu = 1.5$, $S - m$, P. Assuming that the lines $\lambda = 4226.91$ Å. U., $\lambda = 4607.52$ Å. U., and $\lambda = 5535.69$ Å. U. are the first members of the series $\nu = 2$, $p_2 - m$, S, for calcium, strontium, and barium (*i.e.*, that they are given by $\nu = 2$, $p_2 - 1.5$, S), it follows that if $\nu = 2$, p_2 be known for the spectra of these elements then the frequencies represented by $\nu = 1.5$, S can be calculated for them, and these would give the waves of shortest length in the series $\nu = 1.5$, $S - m$, P. Further, a knowledge of the values of $\nu = 2$, P for the spectra of the three elements would then give the first members of the same three series.

From the paper by Dunz it will be seen that for the spectra of calcium and strontium the values $\nu = 2$, p_2 are respectively 34,089.47 and 31,420.38. Taking the frequencies of the lines represented by $\nu = 2$, $p_2 - 1.5$, S for calcium and strontium to be 23,644.25 and 21,705.82, it follows that the frequencies of $\nu = 1.5$, S for these two elements are respectively 57,733.72 and 53,126.2. These frequencies correspond to $\lambda = 1732.1$ Å. U. and $\lambda = 1882.3$ Å. U., and these wave-lengths, therefore, should be the limiting ones in the series $\nu = 1.5$, $S - 2$, P for the two elements mentioned. Again, the frequencies $\nu = 2$, P for calcium and strontium are given in the paper by Dunz [12] as 27,510.2 and 25,745.2, so that,

[12] Dunz, *loc cit.*

combining these with the values of $\nu = 1.5$, S given above, we have 30,223.52 and 27,380.9 as the frequencies represented by $\nu = 1.5$, $S - 2$, P in the spectra of calcium and strontium. As the wave-lengths corresponding to these frequencies are $\lambda = 3308.6$ Å. U. and $\lambda = 3652.2$ Å. U., it would follow that these wave-lengths are respectively the first members of the series $\nu = 1.5$, $S - m$, P in the spectra of calcium and strontium. The paper by Dunz does not appear to contain data which would enable one to determine the frequency $\nu = 2$, P for barium. However, it gives the frequency $\nu = 2$, p_2 as 29,350.4 for this element. Taking then the wave-length $\lambda = 5525.69$ Å. U. as the one whose frequency is given by $\nu = 2$, $p_2 - 1.5$, S in the spectrum of barium, it follows that for this element the frequency $\nu = 1.5$, S is equal to 47,414.99. As this is the frequency of $\lambda = 2109.04$ Å. U., it would appear that for barium this wave-length is the shortest one in the $\nu = 1.5$, $S - m$, P series. From the considerations presented it would appear, therefore, that for calcium, strontium, and barium $\lambda = 4226.91$ Å. U., $\lambda = 4607.52$ Å. U., and $\lambda = 5535.69$ Å. U. are respectively the first members of the series $\nu = 2$, $p_2 - m$, S, and that for the same elements $\lambda = 1732.1$ Å. U., $\lambda = 1882.3$ Å. U., and $\lambda = 2109.4$ Å. U. are respectively the last members of the series represented by $\nu = 1.5$, $S - m$, P. In addition, the first member of the series $\nu = 1.5$, $S - m$, P, in the spectrum of calcium should be $\lambda = 3308.6$ Å. U., and the first member of the same series for strontium, $\lambda = 3652.2$ Å. U. The information regarding the details of the series spectra of barium at present available is not sufficient, apparently, to enable one to calculate the wave-length of the first member of the series $\nu = 1.5$, $S - m$, P for this element.

As the absorption spectra of the vapors of mercury, zinc, cadmium, and magnesium have absorption bands at the two wave-lengths given by $\nu = 2$, $p_2 - 1.5$, S and $\nu = 1.5$, $S - 2$, P, it would follow, from the arguments presented, that if the vapors of calcium, strontium, and barium behave in an analogous manner there should be absorption bands at $\lambda = 4226.91$ Å. U. and $\lambda = 3308.6$

Å. U. in the absorption spectrum of calcium vapor, and also bands at $\lambda = 4607.52$ Å. U. and $\lambda = 3652.2$ Å. U. in the absorption spectrum of strontium vapor. The absorption spectrum of the vapor of barium should contain a band at $\lambda = 5535.69$ Å. U., but, as previously stated, the information available is not sufficient to predict the position of the second absorption band.

As already pointed out above, we have sufficient information available already regarding the absorbing properties of calcium, strontium, and barium vapors to confirm in part the findings just presented, but to confirm them fully additional experiments will have to be made.

V. THE SINGLE-LINE AND ABSORPTION SPECTRA OF THALLIUM.

Ramage,[13] in a paper on the comparative study of the spectra of some of the elements, points out that the flame spectrum of thallium also consists of the single line $\lambda = 5350.65$ Å. U. If we assume, as we have done in dealing with the single-line flame spectra of calcium, strontium, and barium, that the frequency of the line $\lambda = 5350.65$ Å. U. is that of the first line in the series $\nu = 2$, $p_2 - m$, S for the spectrum of thallium (*i.e.*, that it is given by $\nu = 2$, $p_2 - 1.5$, S), then, since for this element Dunz gives the frequency $\nu = 2$, p_2 as 49,262.55, it follows that the frequency $\nu = 1.5$, S for the spectrum of thallium is equal to 67,946.77. This frequency corresponds to the wave-length $\gamma = 1471.74$ Å. U., and this wave-length should, therefore, be the last one in the series $\nu = 1.5$, $S - m$, P of the spectrum of the element thallium.

As the frequency $\nu = 2$, P is not known for the spectrum of thallium, one is not able as yet to calculate the frequency $\nu = 1.5$, $S - 2$, P (*i.e.*, the frequency of the first line in the series $\nu = 1.5$, $S - m$, P).

If we assume the behavior of thallium vapor as regards absorption to be the same as that of the vapor of mercury, zinc, cadmium, and magnesium, we should expect to find absorption bands in its absorption spectrum at the wave-lengths given by the frequencies $\nu = 2$, $p_2 - 1.5$, S and $\nu = 1.5$, $S - 2$, P.

[13] H. Ramage, *Proc. Roy. Soc.*, vol. 70, p. 1 (1907).

Wood and Guthrie, in their paper on the absorption spectra of metallic vapors, state that with thallium they found a strong absorption band at $\lambda = 2380$ Å. U., and fainter ones at λ 3230 Å. U., $\lambda = 3092$ Å. U., and $\lambda = 2530$ Å. U., but they do not seem to have found any indication of absorption at $\lambda = 5350.65$ Å. U., which is the wave-length whose frequency is given by $\nu = 2$, $p_2 - 1.5$, S. It is just possible that it would require high vapor densities and high resolving power to bring out this band, for in the case of zinc vapor it was found necessary to work under these conditions to bring out the absorption band at $\lambda = 3075.99$ Å. U.

VI. THE IONIZING POTENTIALS OF DIFFERENT ELEMENTS.

In the paper by McLennan and Henderson attention was drawn to a paper by Frank and Hertz [14] which described experiments leading to the conclusion that the minimum energy required to ionize an atom of mercury was that acquired by an electron in passing through a fall of potential of 4.9 volts. Attention was also drawn in this paper to a second communication by Frank and Hertz [15] in which it was shown that in the quantum relation $Ve = h\nu$ where $h = 6.6 \times 10^{-27}$ erg sec. 4.9 volts is the potential fall which corresponds to the frequency of the line $\lambda = 2536.72$ Å. U. From this it follows that for mercury atoms at least a knowledge of the wave-length of the single line characterizing the single-line spectrum of this element is sufficient to enable one to calculate the ionizing potential. If the relation just pointed out be applicable generally to all the elements, it follows that if the vapor of an element can be shown to be capable of exhibiting a single-line spectrum the frequency of this single spectral line may be used to deduce the minimum amount of energy required to ionize the atoms of that element. From the considerations already presented in this paper it will be seen that the wave-lengths of the single spectral lines in the single-line spectra of the elements have the frequencies given by $\nu = 2$, $p_2 - 1.5$, S, and, as these frequencies are known for mercury, zinc, cadmium,

[14] Frank and Hertz, *Verh. d. Deutsch. Phys. Ges.*, vol. 10, pp. 457–467, 1914.
[15] Frank and Hertz, *Ibid.*, vol. 11, p. 512, 1914.

magnesium, and probably also for calcium, strontium, barium, and thallium, it follows that if Frank and Hertz have put the correct interpretation upon their experiments—and it may be added here that their experiments have apparently been confirmed quite recently by Newman [16]—then the ionizing potentials for the atoms of all these elements can be calculated by the relation $Ve = h\nu$. The results of this calculation are given in Table I.

TABLE I.

Element	Wave-length with frequency $\nu = 2, p_2 - 1.5, S$		Ionizing potential calculated on basis of conclusions of Frank and Hertz	
Mercury	2536.72	Å. U.	4.9	volts
Zinc	3075.99	" "	3.96	"
Cadmium	3260.17	" "	3.74	"
Magnesium	2852.22	" "	4.28	"
Calcium	4226.91	" "	2.89	"
Strontium	4607.52	" "	2.65	"
Barium	5535.69	" "	2.24	"
Thallium	5350.65	" "	2.28	"

In the paper by McLennan and Henderson it was pointed out that in order to obtain the single-line spectra with mercury, zinc, and cadmium vapors it was necessary that the electrons bombarding these vapors should not possess kinetic energy greater than that acquired in passing through falls of potential of 12.5 volts, 11.8 volts, and 15.3 volts respectively for the three vapors. If the electrons possessed kinetic energy greater than that given by these voltages, visible arcs were struck and the many-lined spectra were obtained for the three elements. In the paper mentioned it was also stated that as these voltages gave with the relation $Ve = h\nu$ approximately the wave-lengths of the limiting lines in the series $\nu = 1.5, S - m, P$ for the three elements, the results might be interpreted as indicating possibly a second type of ionization which the atoms of these elements might be capable of undergoing. If this interpretation should turn out to be correct, it would follow, since the frequency of the limiting lines in the series $\nu = 1.5, S - m, P$ are given by $\nu = 1.5, S$, that the ionizing potentials of the second type are given by $V = h \times (1.5, S)/e$. Applying this relation to the results already obtained and

[16] Newman, *Phil. Mag.*, **28**, pp. 753–756, November, 1914.

given above, the ionizing potentials of the second type have been calculated for mercury, zinc, and cadmium, magnesium, calcium, strontium, barium, and thallium, and are given below in Table II.

TABLE II.

Element	Wave-length corresponding to frequency $\nu = 1.5_2 S$		Ionizing potentials calculated from $V = h \times (1.5_2 S)/e$	
Mercury	1188.0	Å. U.	10.27	volts
Zinc	1320.0	" "	9.24	"
Cadmium	1378.7	" "	8.85	"
Magnesium	1336.1	" "	9.13	"
Calcium	1732.1	" "	7.04	"
Strontium	1882.3	" "	6.48	"
Barium	2109.04	" "	5.78	"
Thallium	1471.74	" "	8.29	"

VII. IONIZING POTENTIALS AND BOHR'S THEORY OF THE ORIGIN OF RADIATION.

In the theory which has been brought forward by Bohr [17] the atom of an element is supposed to consist of a positive Rutherford nucleus surrounded by one or more rings of electrons revolving in stationary or non-radiating orbits about the nucleus. In the neutral or most stable state the electrons are revolving in the orbits of smallest possible area. The diagram in Fig. 8 may be taken to illustrate this point.

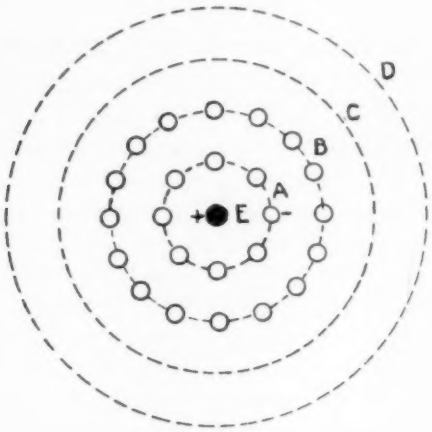
A neutral atom may be supposed, for example, to consist of a positive nucleus E surrounded by two rings of revolving electrons A and B. If through some agency, such as an electronic bombardment, one or more of the electrons in the ring B be made to revolve in the orbit C, then, according to the theory of Bohr, these electrons would not radiate while revolving in the orbit C, but they would send out a radiation of a single determinate wave-length in passing back from the orbit C to the stable orbit B. Extending the theory still further, if the disturbing agency caused one or more of the electrons in the orbit B to revolve in the orbit D, then, as the electrons might drop back either directly to the orbit B or to the orbit C first and then to the orbit B, it would appear that atoms subjected to such a disturbance would be capable, in returning to the neutral state, of emitting a radia-

[17] Bohr, *Phil. Mag.*, **26**, pp. 1, 476, 857 (1913); **27**, p. 506 (1914); **30**, p. 394 (1915).

tion consisting of two and possibly three definite and determinate wave-lengths. It would then seem, from Bohr's theory, that atoms of a vapor bombarded by electrons should be capable of emitting either a single-line spectrum, a two- or three-line spectrum, a four-line spectrum, etc., according to the violence of the shock to which they were subjected.

Again, according to the theory of Bohr, ionization of an atom could only be said to have taken place when the disturbing agency caused one or more of the electrons to be projected out from the electronic system beyond the outermost stationary or non-radiating orbit of the atom. This theory would, therefore,

FIG. 8.



predicate but one type of ionization for atoms. By applying the theory to the matters discussed in the present communication it would appear that atoms in the state to emit a single-line spectrum could not be said to be ionized. It would follow then that if Bohr's theory of the origin of radiation be correct, the interpretation placed by Frank and Hertz on the results of their direct investigation of the ionizing potentials for mercury atoms cannot be the correct one. On the other hand, in the experiments of Henderson and myself in which the single-line spectra were obtained with mercury, zinc, and cadmium vapors when they were bombarded by electrons, the fields in which these bombarding electrons acquired their energy covered a range of from about 5 volts to slightly over 10 volts. It is probable that under

these conditions the great majority of the bombarding electrons would acquire just sufficient energy to stimulate the atoms of the vapors traversed to the emission of a radiation of but a single wave-length. The second absorption bands, however, in the absorption spectra of mercury, zinc, and cadmium vapors, it will be recalled, come at $\lambda = 1849.6$ Å. U., $\lambda = 2139.3$ Å. U., and $\lambda = 2288.79$ Å. U. respectively, and it will be seen, therefore, that if the quantum relation $Ve = h\nu$ be applicable the potential falls corresponding to these wave-lengths are well within the range extending from 5 to 10 volts. One would have expected, therefore, that with arcing potentials of 10 volts one should have found traces at least of the lines $\lambda = 1849.6$ Å. U., $\lambda = 2139.3$ Å. U., and $\lambda = 2288.79$ Å. U. acompanying the lines $\lambda = 2536.72$ Å. U., $\lambda = 3075.99$ Å. U., and $\lambda = 3260.17$ Å. U. in the spectra emitted by the three vapors. No indication of these lines, however, was found in the experiments of Henderson and myself, even with exposures of five hours' duration and with vapors covering a wide range of densities. It should be remembered that, even if some of the atoms of the vapors traversed were stimulated to the emission of the shorter wave-lengths mentioned, the radiation of these wave-lengths might have been absorbed in passing through the outer layers of the vapor in the arcing tube. The experiments of Henderson and myself cannot, therefore, be taken as being opposed to the correctness of Bohr's theory. If, however, this theory be correct, then it does follow that Frank and Hertz have incorrectly interpreted their results. Moreover, if it should turn out that they and also Newman have placed the wrong interpretation on the results of their investigations, then the ionizing potentials for mercury, zinc, cadmium, magnesium, calcium, strontium, barium, and thallium should not be those given in Table I, but they should, in all probability, be those given in Table II, and we should arrive at the conclusion that there is but one type of ionization for atoms.

VIII. SUMMARY OF RESULTS.

1. It has been shown that, like the vapors of mercury, zinc, and cadmium, magnesium vapor, when traversed by electrons, can be stimulated to the emission of a single-line spectrum. The wave-length of this line is given by $\lambda = 2852.22$ Å. U.

2. It has been shown that the absorption spectrum of non-luminous magnesium vapor contains an absorption band at $\lambda = 2852.22$ Å. U. and one at $\lambda = 2073.36$ Å. U.

3. As the lines $\lambda = 2852.22$ Å. U. and $\lambda = 2073.36$ Å. U. are the first members of the series $\nu = 2$, $p_2 - m$, S and $\nu = 1.5$, $S - m$, P respectively, the absorption spectrum of magnesium vapor has been shown to be analogous to the absorption spectra of the vapors of mercury, zinc, and cadmium.

4. Considerations have been presented which indicate that the single-line spectra of calcium, strontium, barium, and thallium vapors under bombardment by electrons should have the wave-lengths $\lambda = 4226.91$ Å. U., $\lambda = 4607.52$ Å. U., $\lambda = 5535.69$ Å. U., and $\lambda = 5350.65$ Å. U. respectively.

5. The ionizing potentials have been deduced for atoms of magnesium, calcium, strontium, barium, and thallium in addition to those for the atoms of mercury, zinc, and cadmium.

6. Considerations have also been presented which show that if Bohr's theory affords an explanation of the origin of single-line spectra, then Frank and Hertz and also Newman must have placed a wrong interpretation on the results of their direct investigation of the ionizing potentials for mercury atoms.

University of Toronto,
November 11, 1915.

Turbines vs. Engines in Units of Small Capacities. J. S. BARSTOW. (*Proceedings of the American Society of Mechanical Engineers,* December 7 to 10, 1915.)—It may safely be said that not until twenty years ago was there any really reliable steam turbine developed, and even as late as ten years ago the turbine was looked upon mainly as an experiment. The last few years, however, have witnessed the practical perfection of this type of prime mover in sizes as large as 50,000 horse-power, with units of 30,000 horse-power quite common in central stations, and for installations of such enormous output the superiority of the turbine is undisputed. In small plants of 500 horse-power or less the turbine still divides honors with the reciprocating engine, and in the present state of the art a judicious selection between them can only be made by a close analysis of all the requirements and by comparing the costs of meeting them with each type of prime mover.

A Mode of Studying Damped Oscillations by Means of Shrinking Vectors. D. ROBERTSON. (*The Journal of the Institute of Electrical Engineers*, vol. 54, No. 251, December 1, 1915.)—The application of rotating vectors to sine waves has proved of very great service in connection with the theory of alternating currents. It has made it possible to form simple mental pictures of the phase relationships, and has facilitated the deduction of formulæ by which calculations can be made. It also allows us to obtain graphical solutions of problems, but this is of less value than the two uses just mentioned.

Damped oscillations can be represented in a similar manner by means of shrinking vectors, and the equations for such oscillations can be deduced from such vectors almost as easily as those for ordinary alternating currents. The vector diagrams bring the theory of the subject completely within the grasp of those to whom the differential and integral calculus are profound mysteries. In fact, the vector method is a valuable means of differentiating and integrating sine functions in a simple manner without any knowledge of the calculus. Even to the mathematician the vector diagram is useful, for it gives a valuable picture of the phase relationships, which permits the equations being written down straight away so as to fulfil the initial conditions, instead of being written first with unknown constants whose values have to be afterwards found from these conditions. The paper is written mainly from the point of view of electrical oscillations, but the method is equally applicable to any kind of vibration.

Una-flow Steam Engines for Electric-plant Operation. ANON. (*Electrical World*, vol. 67, No. 1, January 1, 1916.)—Some very excellent results are announced in the performance of the so-called "una-flow" steam engine. In this engine the exhaust takes place at the end of the stroke through a port in the middle of the cylinder opened and closed by the passage of the piston over it. By this arrangement a constant temperature at any given point of the cylinder is maintained, thus reducing the losses by condensation occurring in other types of engine in which the live and exhaust steam are alternately in contact with the same part of the cylinder.

A una-flow engine built under the Stumpf patents by the Ames Iron Works, Oswego, N. Y., has been installed in the Quitman (Ga.) municipal lighting plant. This is a simple condensing engine with a cylinder 20 inches in diameter and a stroke of 22 inches. It develops about 400 horse-power at 200 revolutions per minute, with a pressure of 165 pounds per square inch, 26-inch vacuum, and steam superheated 100° F. In a test under these conditions, this engine showed a steam consumption of 12.4 pounds per indicated horse-power per hour at one-quarter load, 11.5 pounds at half load, 11.2 pounds at three-quarters load, 11.6 pounds at full load, and 12.5 pounds at 25 per cent. overload. Tests on other engines of the same type are reported as giving substantially similar results.

ARCS IN GASES BETWEEN NON-VAPORIZING ELECTRODES.*

BY

G. M. J. MACKAY

AND

C. V. FERGUSON.

THE object of this note is to indicate the nature of some experiments, to be more fully described later, made during an investigation of the rectifying properties of gases, which tend to throw some light upon arc phenomena and gaseous conduction in general.

The work of Dr. Langmuir [1] upon the emission of electrons from an incandescent filament in vacuum has been extended and applied in the field of electrical conduction through gases at comparatively high pressures.

By the use of tungsten electrodes it has been found possible to construct enclosed arcs which will act as rectifiers of alternating current, and carry 10 to 20 ampères with such slight deterioration of the metal that a life of many hundreds of hours may be obtained. The electrodes operate at temperatures between 2600° and 3200° K., and there appears to be no more loss of material than can be accounted for by the normal rate of evaporation of the tungsten at these temperatures. That this is extremely small is evidenced by the life of the filament in the nitrogen-filled lamp, which operates at about 2800° K. where the vapor pressure is about 3.10^{-5} mm.,

TABLE I.

Temperature, °K.	Vapor pressure, mm.	Rate evap. g. sq. cm. s.	Thermionic current, ampères	Molecules of H_2 per c.c. capable of ionizing
2000	645.10^{-14}	114.10^{-15}	.004	1
2400	492.10^{-10}	798.10^{-12}	.365	10^4
2800	286.10^{-7}	429.10^{-9}	8.98	10^6
3200	333.10^{-5}	467.10^{-7}	96.9	10^8
3540 M.P.	80.10^{-3}	107.10^{-5}	509	10^9
5100 B.P.	760.	.....	57023	10^{12}

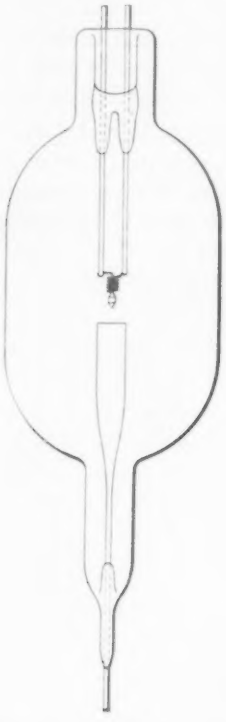
as shown in Table I. There is also some reason for believing that the evaporation is less than would occur due to the high temperature alone, since such tungsten as is evaporated seems to be carried

* Communicated by Dr. Whitney.

[1] *Physical Review*, N. S., ii, p. 450 (1913).

within the arc stream from the anode to the cathode on direct current. If the pressure of the gas be of the order of several centimetres or higher, there is no trace of the so-called "cathode sputtering" which occurs so violently at lower pressures. The reasons for the absence of this effect seem to be: (1) elimination of high cathode drop by a uniformly highly-heated electrode, (2) a comparatively high pressure of gas which lowers the cathode drop

FIG. 1.

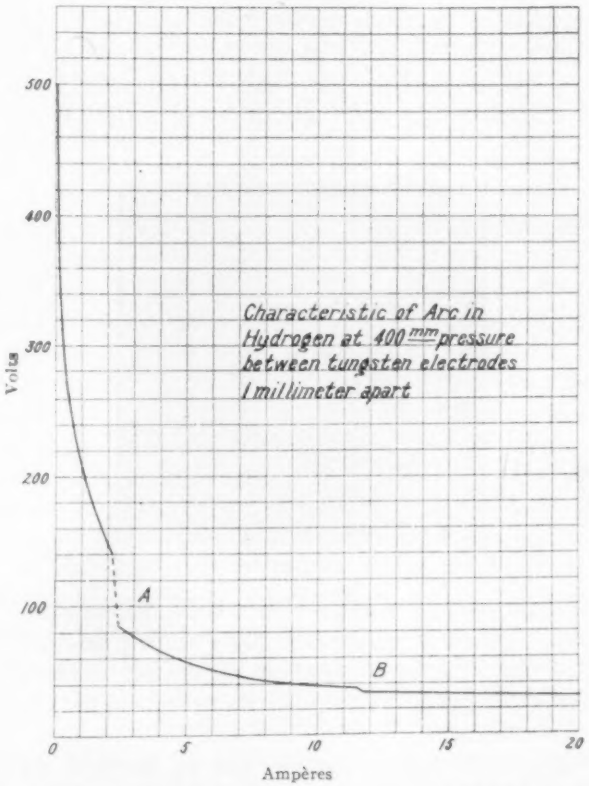


by lessening the mean free path of the impinging positive ions and also lowers the rate of evaporation of the hot metal, as in the case of the filament of the gas-filled lamp.

A typical piece of apparatus used in the investigation is shown in Fig. 1. In order to study the effect of temperature at the cathode this electrode is supplied with a tungsten filament requiring about 20 ampères to heat it to 2800° K. The anode is made large so that it will operate at a comparatively low temperature.

Fig. 2 shows the volt-ampère characteristic of hydrogen as found on direct current with such an arrangement. It will be seen that it has the typical form described by Dr. W. G. Cady,[2] showing an unstable portion at *A*, where the discharge changes with increasing current from an almost invisible glow to a very concen-

FIG. 2.



trated arc discharge, and a less noticeable "kink" at *B*. Other gases, such as nitrogen and argon, however, do not show such well-defined points of instability. A photograph of a similar arc with a longer gap of 6.6 mm. is shown in Fig. 3. The appearance of this arc is very striking; though very thin and of little luminosity, the path is very clearly defined. The energy consumption is also

[2] *Met. and Chem. Eng.*, xiii, p. 866 (1915).

very high, due doubtless to the fact of its more or less complete dissociation into atoms at the temperature involved, and its extremely good thermal conductivity. Thus the arc of Fig. 2, 1 mm. long and 0.5 mm. diameter, consumes 700 watts, operating at 25 ampères and 28 volts. It should be a very good source of ultraviolet radiation.

If the characteristics of the arc are affected to any extent by the evaporation of electrode material, as has been supposed with carbon and low boiling-point metal electrodes, where the vapor pressure of the substance often reaches atmospheric pressure, it should be expected that strikingly different results would be ob-

FIG. 3.

Arc in hydrogen between tungsten electrodes 6.6 mm. apart.

tained with the tungsten arc. Since such differences have not been found, and since many arcs have shown no spectroscopic evidence of the presence of tungsten in the arc stream, it would appear that rapid evaporation plays no necessary part in the conduction of current.

On direct current the nature of the anode, whether large or small, of copper, carbon, or iron, does not appreciably affect the electrical characteristics.

The most interesting and most important phenomena occur at the cathode, which may take the form of a filament as shown above, capable of being heated to various temperatures by an external source of energy. In order for a discharge to have the typical "falling" volt-ampère characteristic shown in Fig. 2, it is necessary that the cathode spot be heated to a comparatively high tem-

perature, approximately 2800° K., either by the application of energy from without or by bombardment of positive ions from the gas.

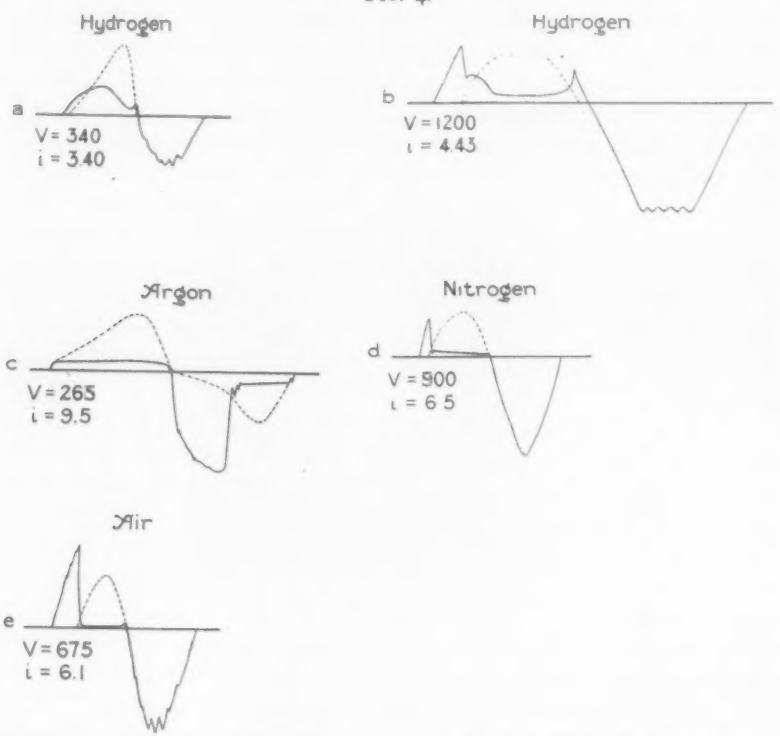
The chief function of a cathode heated from an external supply is the great reduction in sparking or arcing potential, which enables the discharge to be started at a voltage relatively very low in comparison with that necessary between cold electrodes. For instance, an arc in hydrogen with a 1 mm. gap will start on 400 volts if the cathode be heated, whereas with a cold electrode a voltage in the neighborhood of 4000 is required. Once the arc has started, the exciting current may be shut off from the filament, when the discharge will run with very little increase in voltage and maintain its own cathode spot at the proper temperature. The tungsten button in Fig. 1 offers a good design for this purpose, since the " spot " may be removed from the more fragile filament. With lower pressures, of course, much less voltage will start the arc over much wider gaps, and hence the bringing of the electrodes together to strike an arc is obviated and the advantage of a fixed gap length secured.

Fig. 4*c* illustrates these characteristics very well when an arc on alternating current is maintained between a tungsten cathode small enough to be kept hot by the discharge and an anode large enough to operate at a much lower temperature. These wave shapes were determined by oscillograph in argon at 20 cm. pressure. They show how the voltage necessary to start the arc from the hot cathode is no greater than the arc drop itself, whereas on the other half of the cycle, though there is a slight current from the beginning, the anode does not act like the hot cathode until the voltage has reached the peak of the wave. As the anode is allowed to heat, however, this " arcing back " voltage gradually decreases. This current obtained at the beginning of the half cycle when the large electrode is negative is probably due to persistence of the ionization produced during the first half of the wave. It is in sharp contrast to the complete rectification shown in Fig. 4*b*, where the rise of potential at the end of the cycle and the sharp " cut off " indicates a rapid recombination of ions due to their greater rate of diffusion in hydrogen.

Various gases show different characteristics. Fig. 4 shows typical curves for arcs in hydrogen, argon, nitrogen, and air. All give complete rectification of current under proper conditions. It

will be seen that in one case with hydrogen the initial part of the discharge has a positive volt-ampère characteristic, and that there is not the sudden drop from a peak voltage as in the case of most of the others. The last two cases are of interest because there is a chemical reaction occurring between electrodes and the gas with

FIG. 4.



Instantaneous (60-cycle) volt —— ampère - - - - - - characteristics of arcs in different gases. Effective values of volts and ampères.

the formation of volatile compounds of tungsten. With nitrogen there is apparently a film of nitride formed which slowly distils off, since tungsten nitride is formed in gas-filled lamps.[3] It has been thought by some that chemical reaction aids materially in the formation of an arc, but in these cases such conditions are certainly much less favorable than with the "inert" gases, argon and hydrogen.

[3] I. Langmuir, *Journ. Am. Chem. Soc.*, XXXV, p. 931 (1913).

In fact, in the case of argon, when very carefully purified, a total arc drop at 5 centimetres pressure is obtained that is less than 4 volts, which is considerably less than the ionization potential of 12 volts determined by Frank and Hertz.[4] The arc drop in the gas itself also appears to be less than ½ volt per centimetre.

This effect of reacting gases, such as nitrogen, oxygen, etc., on the starting of the above arcs, is very similar to the inhibiting effect on electron emission found by Langmuir.[5]

From the standpoint of rectification, interesting differences occur at different pressures. For instance, while hydrogen rectifies as well if not better at high pressure than at a few millimetres, argon, under the same conditions, seems to operate much better at pressures less than 10 centimetres. This seems to be due to a sudden change in the character of the discharge which occurs at about 12 centimetres, when the diffuse arc which exists at the lower pressure goes over into a more concentrated form with a small anode spot. This type of discharge apparently liberates heat at the anode so locally that "arc back" occurs at relatively low voltages on alternating current.

From the foregoing it would therefore appear that rapid vaporization and chemical reaction at the electrode surfaces are merely incidental to the physical phenomena involved, which are undoubtedly the most important.

Effects which must be considered are: (1) thermionic emission from the hot cathode, (2) thermionic emission from the hot gases, (3) effect of temperature on the gas to increase the kinetic energy of the molecules so that ionization may be produced by impact as suggested by J. J. Thomson, and (4) secondary electron emission from the hot cathode due to bombardment by positive ions.

Dr. Langmuir has shown that Richardson's equation for the current emitted by an incandescent body holds for tungsten at all temperatures, and has determined the constants as follows:

$$i = 23.6 \times 10^6 \sqrt{T}\, e^{-\frac{52,500}{T}}$$

Now these currents cannot be attained in high vacuum without employing very high voltage, on account of the mutual repulsion

[4] *Ber. d. deutsch. Phys. Ges.*, **15**, p. 34 (1913).

[5] *Loc. cit.*

of the similarly-charged particles. This "space charge," however, is destroyed in gases by the positive ions produced by collision, so that the maximum electron emission may be realized at low voltages.

Below are tabulated the vapor pressure and the rate of evaporation in grammes per square centimetre per second of tungsten at different temperatures, the thermionic current as calculated by the above equation, and the number of molecules of hydrogen per cubic centimetre, which possess a kinetic energy corresponding to the ionization potential of 11 volts, calculated from the average kinetic energy of the molecule and Maxwell's distribution law.

The rate of evaporation of tungsten in an inert gas at atmospheric pressure is about 1 per cent. of the value in vacuum given above.

The currents obtained in practice are several-fold the normal thermionic emission, but, as the temperature of the gas is undoubtedly very high, it may be highly thermionic, so that with secondary electron emission it is not surprising that high conductivity of the different media exists. Thermal agitation of the gas is apparently too small to account for any great conductivity, though at the temperatures which may be involved its influence may be far from negligible.

It is hoped in the near future to publish a more quantitative study of these arcs, and to give data regarding the electrode drops in different gases under various conditions. The tungsten arc offers a very good opportunity for this, because by an optical pyrometer the temperature distribution of well-defined electrodes can be measured, consequently the watts radiated and conducted determined from existing lamp data, and so the electrode drops determined from the relationship

$$W = V \times I$$

the current being, of course, constant. The application of such arcs will also be discussed from the following viewpoints: high-frequency generators, rectifiers, and spectra of gases under different electrical conditions.

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THE APPLICATION OF THE PAPER PULP FILTER TO THE QUANTITATIVE ESTIMATION OF CALCIUM AND MAGNESIUM.*

BY

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AND

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INTRODUCTION.

THE elements calcium and magnesium play a great rôle not only in the mineral kingdom, but also in the organic world, since they are absolutely indispensable to both the vegetable and animal cell. The importance of calcium ions for the life phenomena of the cells is easily comprehended when we consider that calcium is contained in bones, muscles, brain, blood, and the glands of animals, as well as in the membrane of plants; that calcium facilitates the transportation of carbohydrates in plants and precipitates the toxic oxalic acid in cells, and so forth.

The magnesium salts, too, display a variety of functions which have been studied, especially in their relation to the functions of calcium. Ever since Ringer [1] has shown that the toxic effect of potassium can be paralyzed by means of calcium, the question of the antagonism between calcium and magnesium, as well as between various salts generally speaking, is being studied and discussed by a number of investigators. Osterhout,[2] *e.g.*, has demonstrated that the toxic action of pure sodium chloride solution on algæ can be inhibited by the addition of calcium chloride.

True and Bartlett [3] have shown that calcium salts are absorbed

* Amplified form of a paper presented before the Second Pan-American Scientific Congress, Washington, January 4, 1916, and published by permission of the Secretary of Agriculture.

[1] *Jour. of Physiol.*, **3**, 380 (1880–82); **4**, 29 (1883–84); **5**, 247 (1884–85).

[2] *Journ. Biol. Chem.*, **1**, 366 (1905–06).

[3] True, R. H., and Bartlett, H. H., U. S. Dept. of Agric., Bureau of Plant Industry, Bull. 231, 1912; *Amer. Journ. Bot.*, **2**, 255 (1915); **2**, 311 (1915). See also True, Rodney H., *Amer. Journ. Bot.*, **1**, 255 (1914).

by plants (*Lupinus albus*) at a greater range of concentrations than magnesium salts, and that the calcium salts apparently enable the plants to retain possession of the salts already present, and, further, that there is a certain ratio of magnesium to calcium which favors maximum absorption, while Loew[4] has demonstrated that the toxic action of magnesium salts on plants can completely be paralyzed by calcium salts. The antagonism which has been shown to exist between calcium and magnesium (and other electrolytes) in plants holds also true for the animal organism, as was experimentally demonstrated by Meltzer and Auer,[5] Loeb,[6] and others. Inasmuch as in experiments of the above indicated nature the experimenter is frequently confronted with the necessity of estimating calcium and magnesium in whole series of culture solutions before and after the plants have grown in them for a certain length of time, or in various plant and animal materials, or in feeding stuffs offered animals as well as in their organs and tissues, a speedy and at the same time accurate method for the determination of calcium and magnesium seems to be indispensable. While the present methods for their quantitative determinations are accurate, they have the disadvantage of requiring too much time. In this paper it will be shown that the pulp filter, which was shown by the writers[7] to be superior to either filter paper or asbestos for the filtration of the ammonium phosphomolybdate precipitate, can successfully be applied to the filtration of calcium oxalate and magnesium ammonium phosphate as well.

EXPERIMENTAL.

Preparation of Chestnut Bark for Analysis.

Having occasion to determine calcium and magnesium in a number of chestnut-bark samples, healthy and infected, we have decided to apply the pulp filter to the estimation of these elements. Bark removed from various chestnut trees was cut to small slices, dried, ground, and finally passed through a 30-mesh sieve. The bark powder obtained was burned in an electric muffle oven where the heat was gradually increased to a dull red heat until the

[4] *Landwirtsch. Jahrb.*, **46**, 733 (1914); *Biochem. Zeitschr.*, **38**, 236 (1912).
[5] *Centralb. f. Physiol.*, **21**, 788 (1907); *Biochem. Zeitschr.*, **38**, 238 (1912).
[6] *Biochem. Zeitschr.*, **32**, 308 (1911).
[7] Jodidi and Kellogg, *Biochem. Bulletin*, vol. 4, 1915.

residues represented a uniform gray ash, which was used for analysis.

Two grammes of bark ash were carefully dissolved in dilute hydrochloric acid and evaporated to dryness, the treatment with acid and evaporation being repeated three times. The final dust-dry residue was treated with hydrochloric acid, filtered and thoroughly washed with hot water. Filtrate and washings from the insoluble residue—which consisted of silica, sand, and carbon—were cooled and made up to 500 c.c. Of this solution (*S*) several portions of 50 c.c. each were treated as follows: On being neutralized with ammonia, the solution was slightly acidified with acetic acid, when 0.5 c.c. of ferric chloride and 5 to 6 c.c. of concentrated ammonium acetate solution were added and the whole heated to boiling. The brown precipitate (basic ferric, aluminic—phosphate and acetate) was rapidly filtered off and washed with a boiling hot very dilute solution of ammonium acetate, filtrate and washings being used for calcium estimation.

Gravimetric Estimation of Calcium.

The ordinary [8] method of calcium determination involves, as is known, repeated decantation, filtration, and washing of the calcium oxalate precipitate, which, if magnesium is present (as was the case with the chestnut-bark ash), has to be redissolved and reprecipitated, which necessitates a repetition of all mentioned operations. The final calcium oxalate obtained is on drying to be separated from the filter, in order to be burned separately, etc. The employment of the paper pulp filter, which completely retains the calcium oxalate precipitate despite rapid filtration, permits of doing away with most of the above operations, which require considerable time, labor, and attention. The method adopted for the work with the pulp filter was as follows:

A Gooch crucible is placed in a somewhat larger platinum [9] crucible with cover and both are heated, cooled, and weighed together. The Gooch crucible is now placed in the funnel of a suction flask, provided with a pulp filter, whereupon the calcium [10]

[8] Fresenius, "Quantitative Chemical Analysis," vol. i, pp. 235–6 (1903).

[9] The platinum crucible is used to prevent loss, which could occur if the pulp filter with the calcium oxalate would be heated directly in the Gooch crucible.

[10] The precipitation of calcium took place always in 50 c.c. of solution (*S*), equal to 0.2 gramme of bark ash.

oxalate obtained, as usual, with ammonium oxalate in slightly ammoniacal solution is (on standing for twelve hours), *together with the supernatant liquid, at once* filtered [11] off into the crucible. The beaker, in which traces of calcium oxalate may remain, is now rinsed out several times with boiling hot water, which is also used for washing the precipitate in the Gooch. The operation of filtering off the precipitate and washing it free from foreign matter goes very rapidly, taking altogether about five minutes. Because of the presence of not insignificant proportions of magnesium in the chestnut-bark ash, the precipitate in the Gooch crucible is now redissolved by means of hot dilute hydrochloric acid—which can be added by stirring up the precipitate with a stream from the nozzle of a wash bottle—and thoroughly washed with hot water. Solution and washings are allowed to run into the precipitation beaker, where the redissolved calcium oxalate is heated to boiling and, with addition of a few cubic centimetres of ammonium oxalate and of ammonia in some excess, reprecipitated. On standing on the steam bath for about thirty minutes the precipitate, on being stirred up with the supernatant liquid, is filtered off quantitatively on the same pulp filter and thoroughly washed with hot water. The Gooch is now placed in the platinum crucible (with which it was weighed) and the precipitate with the pulp filter is directly [12] heated over the Bunsen burner, the small flame of which is at first cautiously directed towards the fore-part of the inclined crucible, where there is no substance, in order to remove the moisture. When the flame is gradually increased and moved backwards it causes the pulp filter first to carbonize, and, when it begins to burn, it is very readily burned to ash, sometimes with sparkling, throughout the whole mass, due to the more or less finely divided state of the paper fibre of which the pulp filter is made up. By finally burning the substance in the covered crucible over the blast [13] burner, as usual, it is finally converted to calcium oxide. The results are presented in Table I.

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[11] The filtrate is, as a rule, faultlessly clear, and does not need any refiltration.

[12] The precipitate with the filter may, of course, be warmed in the oven until nearly dry before they are burned; the drying, however, is not necessary for obtaining good results.

[13] Or Meker's burner.

TABLE I.

Chestnut-bark ash, No.	Analysis No.	CaO found		Remarks
		Gramme	Per cent.	
1	* 1[14]	0.0947	47.35	This was healthy bark taken from a chestnut tree about 14 years old, with a periphery of 15½ inches. Only the top of the chestnut was still living.
	* 2	0.0947	47.35	
	3	0.0949	47.45	
2	* 4	0.0840	42.00	The infected bark of No. 2 was taken from the same chestnut (see No. 1). The canker was one year old.
	5	0.0839	41.95	
3	* 6	0.0868	43.40	This was healthy bark taken from a chestnut tree 22 years old. Only the upper branches of the tree were covered with leaves.
	* 7	0.0870	43.50	
	8	0.0876	43.80	
4	* 9[15]	0.0867	43.35	The infected bark of No. 4 was taken from the same tree as in No. 3. The canker was one or two years old.
5	*10	0.1005	50.25	No. 5 was made up of barks taken from several infected trees. The cankers were from one to three years old.
	11	0.1016	50.80	

While the question of any relationship between the fungus metabolism, on the one hand, and the percentage of the inorganic constituents in the barks, on the other, needs considerably more data and will be discussed in another paper, it may be mentioned here that the corresponding healthy and infected chestnut-bark samples were taken from the same trees in order to exclude the influence of age, since the percentage of calcium in bark usually increases with age, just as the proportion of magnesium decreases. A glance at Table I shows that the analyses Nos. 1 and 2, the precipitates of which were filtered through pulp, agree well with each other, just as they agree with the check analysis No. 3, the precipitate of which was filtered through standard quantitative filter paper. This is also true of all the other analyses, despite the fact that the filtration [16] and washing on the pulp filter takes only

[14] In the analyses designated with a * the calcium oxalate precipitate was filtered on a pulp filter, while in the rest of the analyses, which represent the controls, the precipitate was filtered on quantitative filter paper (S. & S. No. 590).

[15] The check analysis corresponding to No. 9 was lost.

[16] Decantation is here unnecessary.

some five minutes, instead of from 30 to 35 minutes required for the paper filter.

Since, in the presence of magnesium, calcium oxalate has to be redissolved and reprecipitated, as was the case with the chestnut-bark ash, it means that the application of the pulp filter to the calcium determination enables one to save in this case about one hour's time for each analysis, which is especially important when series of analyses are to be made.

When in analytical (or synthetical) work the precipitate only is desired, the substance may be filtered through the pulp filter into an ordinary suction flask. If, however, both precipitate and filtrate are necessary, it is best to catch the filtrate directly in the vessel—beaker, dish, or flask—in which it is intended to subject the filtrate to further treatment, thus doing away with the necessity of transferring the filtrate from the suction flask to the desired vessel, which involves loss of time and labor as well as dilution of the substance. For the purpose indicated, we are employing to our full satisfaction Witt's [17] filtering apparatus. Instead, however, of a ground-in funnel, we are using the Gooch crucible placed in a filter funnel which fits in a one-hole rubber stopper. The stem of the funnel is bent so as to touch the wall of the receiving beaker (or flask), thus avoiding loss of substance through spattering. A crystallizing dish may conveniently be used as support for dishes or small beakers (see Fig. 1). For catching filtrates in large flasks or dishes we are using the bell-jar filtering apparatus with the arrangement employed in Witt's apparatus.

Volumetric Estimation of Calcium.

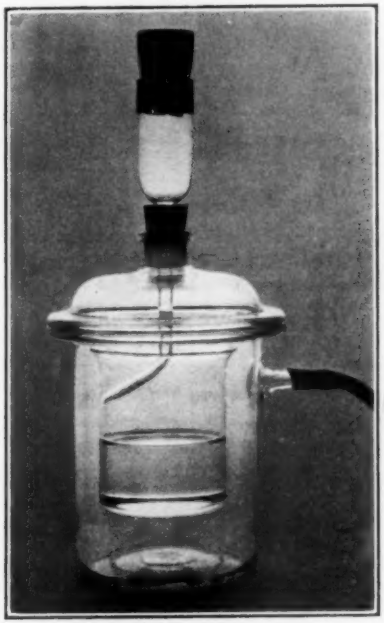
In the determination of calcium by titrating the oxalic acid combined with it with standard potassium permanganate solution, it is recommended in the literature [18] that, prior to the titration, the calcium oxalate precipitate be quantitatively separated from the filter paper. This, of course, requires additional work. Our ob-

[17] A new analytical suction filter which does not seem yet to be on the market and is in the main a modification of Witt's filtering apparatus is described in *Journal of the American Chemical Society*, **37**, 1519 (June, 1915).

[18] Abderhalden, "Handbuch der biochem. Arbeitsmethoden," vol. i, p. 407 (1910). Hoppe-Seyler's "Handbuch der Physiol. und Pathol. Chem. Analyse," p. 545 (1909). C. Neuberg, "Der Harn," vol. i, p. 169 (1911). Treadwell, "Analytical Chemistry," First Edition, vol. ii, p. 491.

servations go to show that the pulp filter in no way interferes with the accuracy of the titration. We proceed as follows: The calcium oxalate precipitate, filtered and washed on the pulp filter, as outlined in the gravimetric estimation of calcium, is by means of a glass rod transferred to the precipitation beaker, *together* with the pulp filter. To remove traces of calcium oxalate from the Gooch crucible, the latter is placed in a glass funnel under which the precipitation beaker stands. Now hot dilute sulphuric acid

FIG. 1.



(some 350 c.c. of water + 10 c.c. of concentrated H_2SO_4) is poured on the Gooch, whereupon the beaker content is stirred for a few seconds with a glass rod which reduces the pulp filter cake to pulp and dissolves the calcium oxalate completely. On heating to about 70 to 80° C., the oxalic acid is titrated with standard potassium permanganate solution, usually tenth-normal. The volumetric estimation of calcium as outlined can be accomplished in very much less time than by the ordinary method. Thus, five consecutive volumetric calcium estimations to which the pulp filter (prepared from S. & S. paper filters, No. 589) was applied

required one hour, which means twelve[19] minutes per analysis. Yet the analyses in all of which equal volumes of the same calcium chloride solution were employed closely agreed with each other, the figures in question being, respectively, 14.75, 14.73, 14.78, 14.77, 14.70 c.c. of n/10$KMnO_4$. In order to have an impartial judgment as to whether or not the pulp filter gives as accurate results as standard quantitative filter paper, it was deemed advisable to run a number of parallel analyses, which are reported in Table II.

TABLE II.

Chestnut-bark ash No.	Analysis No.	Standard $KMnO_4$ used, c.c.	CaO found		Average	Remarks
			Gramme	Per cent.		
1	* 1[20]	33.25	0.0936	46.80	46.85	Check analysis corresponding to analyses Nos. 1 and 2 was lost. 1 c.c. $KMnO_4$ = 0.002814714 gr. CaO.
	* 2	33.33	0.0938	46.90		
2	* 3	29.60	0.0830	41.50	41.50	1 c.c. $KMnO_4$ = 0.0028045 gr. CaO.
	* 4	29.60	0.0830	41.50		
	5	29.39	0.0824	41.20	41.40	
	6	29.50	0.0827	41.35		
	7	29.70	0.0833	41.65		
3	* 8	30.63	0.0859	42.95	43.08	1 c.c. $KMnO_4$ = 0.0028045 gr. CaO.
	* 9	30.80	0.0864	43.20		
	10	30.70	0.0861	43.05	43.05	
	11	30.70	0.0861	43.05		
4	*12	30.42	0.0853	42.65	42.72	1 c.c. $KMnO_4$ = 0.0028045 gr. CaO.
	*13	30.50	0.0855	42.75		
	*14	30.50	0.0855	42.75		
	15	30.19	0.0847	42.35	42.42	
	16	30.42	0.0853	42.65		
	17	30.12	0.0845	42.25		
5	*18	35.68	0.1001	50.05	49.97	1 c.c. $KMnO_4$ = 0.0028045 gr. CaO.
	*19	35.52	0.0996	49.80		
	*20	35.68	0.1001	50.05		
	21	35.60	0.0998	49.90	49.97	
	22	35.79	0.1004	50.20		
	23	35.50	0.0996	49.80		

An examination of Table II reveals the fact that the analyses whose calcium oxalate precipitates were filtered through pulp

[19] From the beginning of the filtration of the calcium oxalate to the end of the titration.

[20] The * in front of the numbers designates that the *pulp* filter was applied to the analyses in question, while in the rest of the analyses filter paper (S. & S., No. 590) was employed for the filtration of the calcium oxalate precipitate.

show concordant results, agreeing at the same time with the check analyses whose precipitates were filtered on good quantitative filter paper (No. 590, S. & S.). This is true, *e.g.*, of analyses Nos. 3 and 4, on the one hand, and 5, 6, 7, on the other, or of 18, 19, 20, on the one side, and 21, 22, 23, on the other.

The question naturally arises as to whether or not the methods described for estimation of calcium in chestnut-bark ash have general applicability. To answer this question the following experiments were performed.

Twenty grammes of calcium chloride ($CaCl_2$, 2aq.) were dissolved in water and made up to four litres. In six portions of this solution the calcium was precipitated as oxalate in the ordinary way, with the results recorded in Table III.

TABLE III.

No. of analysis	Of solution used, c.c.	CaO found, gramme	Remarks
1	50	0.0859	The calcium oxalate precipitates were left in the beakers over night and were filtered next morning on S. & S. paper filters, No. 590.
2	50	0.0855	
3	25	0.0422	
4	25	0.0423	
5	25	0.0425	
6	25	0.0423	
Average in 25 c.c.		0.0425	

In ten other portions of the above solution the calcium precipitated in the form of oxalate was filtered on standing on the steam bath for from 15 to 30 minutes. The results obtained are expressed in the following table:

TABLE IV.

No. of analysis	Of solution used, c.c.	CaO found, gramme	Remarks
1	25	0.0422	In Nos. 1, 2, 7, 8, 9, and 10 the calcium oxalate precipitates obtained in the ordinary way were allowed to stand on the steam bath for half an hour prior to their filtration, while in Nos. 3, 4, 5, and 6 the precipitates were filtered on standing on the steam bath for but 15 minutes.
2	25	0.0425	
3	25	0.0427	
4	25	0.0424	
Average		0.0424	
5	25	0.0424	
6	25	0.0424	
7	25	0.0421	
8	25	0.0424	
9	25	0.0426	
10	25	0.0423	
Average		0.0424	

From the data presented in Tables III and IV it is evident that from pure calcium chloride solution the calcium could be precipitated quantitatively within fifteen to thirty minutes. Since the analyses Nos. 1 to 4 whose calcium oxalate precipitates were filtered through good filter paper (S. & S. filters, No. 590) closely agree with the analyses 5 to 10 whose precipitates were filtered through paper pulp, it follows that the pulp quantitatively retained the calcium oxalate precipitates despite rapid filtration.

In six further portions of the above calcium chloride solution the calcium oxalates filtered and washed on pulp were titrated with standard potassium permanganate solution as outlined in this paper. The results in question are expressed in the table below.

Examination of Table V reveals the fact that the volumetric analyses show concordant results which stand in good agreement with the corresponding gravimetric analyses recorded in Table IV.

TABLE V.

No. of analysis	Of solution used, c.c.	Standard $KMnO_4$ used, c.c.	Corresponding CaO, gramme	Remarks
1	25	15.03	0.0423	1 c.c. $KMnO_4$ = 0.002814714 gr CaO.
2	25	15.03	0.0423	
3	25	15.01	0.0422	
4	25	15.04	0.0423	
5	25	15.05	0.0424	
6	25	15.04	0.0423	
Average			0.0423	

Thus the data obtained with calcium chloride solution fully confirm the results secured with chestnut-bark ash. In other words, the paper pulp is generally applicable to the quantitative estimation of calcium, no matter whether it is to be determined in inorganic compounds or in biological materials.

In all of the calcium estimations reported in this paper (see Tables I to V) the filtrates from calcium oxalate filtered on paper pulp were, as a rule, at once perfectly clear, in spite of the fact that the quantitative filtration and complete washing of each individual calcium oxalate precipitate required but five or six minutes. In one or two cases, however, the calcium oxalate passed through the pulp filter and refiltrations were necessary. It seemed desirable more definitely to ascertain the conditions under which the calcium oxalate precipitate passes through the pulp filter, or is

completely retained by it. With this object in view ten grammes of calcium chloride were on solution in water made up to two litres. Various portions of this solution were uniformly made up with water to a total volume of 200 c.c., heated to boiling when the calcium was precipitated with boiling-hot ammonium oxalate solution, and the whole made slightly ammoniacal. On standing on the water-bath for about an hour, the precipitate was stirred up and together with the liquid filtered on a pulp filter, washed with hot water, and titrated with standard potassium permanganate solution. The results are summarized in Table VI.

TABLE VI.

No. of analysis	Of solution used, c.c.	Filtration (only) required, minutes	$KMnO_4$ used, (1 c.c. = 0.0028595 gr. CaO), c.c.	Corresponding CaO, gramme	Remarks
1.....	10	0.7	5.75	0.0164	Filtrate (from calcium oxalate) perfectly clear.
2.....	10	0.6	5.71	0.0163	Filtrate perfectly clear.
3.....	25	0.6	14.50	0.0415	Filtrate perfectly clear.
4.....	25	1.0	14.53	0.0415	Filtrate perfectly clear.
5.....	50	2.0	29.20	0.0835	Filtrate perfectly clear.
6.....	50	2.0	29.20	0.0835	Filtrate perfectly clear.
7.....	100	14.0	58.30	0.1667	Filtrate not quite clear. One refiltration gave clear filtrate.
8.....	100	....	.....	.....	Very cloudy. Refiltration unsuccessful.
9.....	200	....	.....	.....	Filtrate very cloudy. Three refiltrations did not give clear filtrate.

From the data given in the table it would appear that the concentration of the liquid in which calcium is precipitated as oxalate plays a considerable rôle. In other words, *cæteris paribus,* the calcium oxalate precipitates formed in dilute solutions seem to consist of better, larger crystals which filter well through pulp and give at once perfectly clear filtrates. Thus the filtration (and washing) of calcium oxalate on a pulp filter requires the less time, the smaller is the amount of calcium used. The filtrate from calcium oxalate was perfectly clear so long as the amount of calcium oxide ranged from about 0.01 gramme CaO (or less) to 0.10 gramme CaO. When amounts larger than 0.10 gramme CaO

(= 0.23 gramme calcium oxalate) are analyzed, the filtrate from calcium oxalate is cloudy, provided the precipitation of calcium oxalate takes place in a volume of but 200 c.c. of liquid.

From the above it would follow that in analyzing larger amounts of calcium it is necessary to precipitate it as oxalate in larger volumes in order to get at once clear filtrates, which was actually confirmed by experiments. At any rate, in the application of the pulp filter to the analysis of calcium it is, for the reasons stated, advantageous to use small amounts of substance. In this connection it seems reasonable to assume that the difficulties encountered in the filtration of calcium oxalate precipitates, which not infrequently pass * through paper filters and necessitate repeated refiltration, may in part be due to the fact that the precipitation of calcium as oxalate is performed in not dilute enough solutions.

Gravimetric Estimation of Magnesium.

As in the case of calcium, the application of the pulp filter enables one to eliminate tedious operations incidental to the ordinary method of magnesium estimation, such as repeated decantation, filtration, and washing of the magnesium ammonium phosphate precipitate, as well as its drying and separation from the filter before its ashing. The way we proceeded was as follows: The filtrates and washings from the calcium oxalate precipitates (corresponding to 0.2 gramme of chestnut-bark ash) were evaporated on the steam bath to dryness, freed from ammonium salts by gentle ignition, whereupon the residues were treated with dilute hydrochloric acid, filtered and washed quantitatively. In the combined filtrate and washings the magnesium was precipitated, as usual, in the form of $MgNH_4PO_4$, which, on standing for twelve hours, was, *together with the supernatant liquid*, at once filtered and washed with 2½ per cent. ammonia on a pulp filter.[21] The quantitative filtration and washing of the magnesium

* Abderhalden, Handbuch Biochem. Arbeitsmeth., vol. i, p. 406 (1910); Treadwell, Analyt. Chemistry, vol. ii, p. 66 (1907); Fresenius, Quant. Anal., vol. i, p. 235 (1903); Hoppe-Seyler's Handbuch Physiol. and Pathol. Chem. Anal., 8th Edition, p. 545 (1909).

[21] If not otherwise stated, the arrangements for the platinum and Gooch crucibles, for the filtration of the magnesium ammonium phosphate precipitate, and so on, were made exactly as described in the estimation of calcium.

ammonium phosphate on the pulp filter takes only from three to six minutes, as against about a half-hour required for the paper filter. The Gooch placed in the platinum crucible (with which it was weighed) is now heated directly [22] over the burner, at first very cautiously, gradually increasing the flame, and finally igniting the covered crucible over the blast burner until the substance is converted to magnesium pyrophosphate.

In spite of the rapid filtration of the magnesium phosphate precipitate, the results which are expressed in Table VII show that

TABLE VII.

Chestnut-bark ash No.	Analysis No.	$Mg_2P_2O_7$ found Gramme	Corresponding MgO		Average
			Gramme	Per cent.	
1	* 1[23]	0.0627	0.02272	11.36	11.42
	* 2	0.0633	0.02294	11.47	
	3	0.0630	0.02283	11.42	11.42
2	* 4	0.0505	0.01833	9.16	8.96
	* 5	0.0483	0.01749	8.75	
	6	0.0498	0.01804	9.02	9.02
3	* 7	0.0785	0.02845	14.23	14.38
	* 8	0.0801	0.02903	14.52	
	9	0.0744	0.02805	14.03	
	10	0.0781	0.02831	14.16	14.12
	11	0.0781	0.02831	14.16	
4	*12	0.0638	0.02311	11.56	11.66
	*13	0.0631	0.02285	11.43	
	*14	0.0652	0.02361	11.81	
	*15	0.0653	0.02365	11.82	
	16	0.0650	0.02354	11.77	11.77
5	*17	0.0339	0.01228	6.14	6.12
	*18	0.0337	0.01221	6.11	
	19	0.0320	0.01159	5.80	5.80

the precipitate is quantitatively retained by the pulp filter, since the magnesium estimations whose precipitates were filtered on pulp agree very well with the check analyses whose precipitates were filtered on standard quantitative filter paper.

[22] Drying the pulp filter with the precipitate prior to ashing is here not essential for obtaining accurate results, as direct experiments have convinced us.

[23] As in Tables I and II, the * in front of the numbers designates that the *pulp* filter was applied to the analyses in question.

It seemed desirable to ascertain the percentage of saving with various kinds of filter paper when used as pulp. Hence, three S. & S. filters, No. 595, of 11 cm. diameter, were reduced with water to pulp which yielded in Gooch crucibles twelve pulp filters. Five consecutive volumetric calcium estimations whose calcium oxalate precipitates were filtered through these pulp filters required for the same amount of calcium solution 29.71, 29.70, 29.70, 29.70, 29.72 c.c. n/10 $KMnO_4$ respectively. Equally, three S. & S. filters, No. 589, of 12½ cm. diameter, were reduced to pulp which was sufficient for making fourteen pulp filters. Quantitative analyses whose precipitates were filtered through the pulp filters gave accurate results.

In like manner three filters of 9 cm. diameter which were cut from S. & S. sheet filter paper, No. 598, when reduced with water to pulp yielded twelve pulp filters. Three consecutive phosphoric acid estimations, in all of which equal volumes of the same phosphate solution were used, required for neutralization of the yellow precipitates (filtered through the pulp filters) 10.95, 10.81 and 11.00 c.c. n/2 NaOH respectively. Two further estimations in which the yellow precipitates were filtered through pulp filters prepared from S. & S. filters, No. 588—which from our previous work were known completely to retain the ammonium phosphomolybdate precipitate—required for neutralization of the yellow precipitates 10.95 and 10.95 c.c. n/2 NaOH respectively. Finally, three filters of 11 cm. diameter which were cut from commonest sheet filter paper (used for technical work) were reduced with 150 c.c. water to pulp, to which now 150 c.c. of 20 per cent. hydrochloric acid were added and the whole left over night. Next morning the pulp mass was sucked off on a "nutsche" and washed with hot water. The washed pulp was shaken with water (450 c.c.) to an emulsion which yielded on Gooch crucibles seventeen pulp filters. This experiment was repeated with the same result. Three consecutive phosphoric acid estimations in which the yellow precipitates were filtered through the pulp filters required for neutralization of the yellow precipitates (obtained from equal volumes of the phosphate solution) 11.05, 10.91, 10.90 c.c. n/2 NaOH respectively. As check three other estimations were made whose yellow precipitates were filterd through pulp prepared from S. & S. filters, No. 588. They gave respectively 10.89, 10.91, 10.99 c.c. n/2 NaOH.

The above analyses show that the pulp filters prepared from various kinds of filter paper quantitatively retain the precipitates in question. For the sake of convenience the data are expressed in Table VIII.

It is hardly necessary here to mention that the larger and thicker the paper filters are, the more pulp filters they yield on

TABLE VIII.

Kind of paper filters used	Diameter of paper filters, cm.	Paper filters used, number	When reduced with water to pulp they yielded pulp filters (Gooch) number	Economy of filter paper, per cent.
S. & S., No. 595.....	11	3	12	300
S. & S., No. 589.....	12½	3	14	367
S. & S., No. 598.....	9	3	12	300
Commonest sheet filter paper	11	3	17	467

reduction with water, and *vice versa*. The paper filters used in the experiments of Table VIII were of the sizes which are frequently employed in quantitative analysis.

CONCLUSIONS.

1. The application of the pulp filter to the filtration of the calcium oxalate precipitate enables one to eliminate the tedious operations of repeated decantations, filtrations, washings, etc., and to save half an hour for calcium estimation. In case, however, the calcium oxalate precipitate has to be redissolved and reprecipitated, as is, *e.g.*, necessary in the presence of a considerable percentage of magnesium, the saving of time is about one hour for each individual analysis.

2. It is possible, by the application of the pulp filter, to make a volumetric calcium estimation in about twelve [24] minutes, which is about one-third or one-quarter the time necessary for an analysis when filter paper is used for the filtration of the calcium oxalate precipitate.

3. By employing pulp filter for the filtration of the magnesium

[24] Counting the time from the beginning of the filtration of the calcium oxalate precipitate to the end of the titration.

ammonium phosphate precipitate one is able to do away with the tedious operations incidental to the work with filter paper and to gain about a half-hour's time for each analysis.

4. The work with the pulp filter gives as accurate results for calcium and magnesium as the work with standard filter paper.

5. By using for filtration pulp [25] instead of paper, one is able to economize from 300 to 467 per cent. of filter paper.

WASHINGTON, D. C., December, 1915.

[25] The pulp was obtained from S. & S. filters, No. 589 (see p. 15).

Process for Producing Colored Photographic Prints. ANON. (*Scientific American*, vol. cxiii, No. 24, December 11, 1915.)—A new adaptation of the three-color process of photography in the colors of Nature, the product of the efforts of the well-known worker in this field, Frederick E. Ives, makes possible the production of photographic prints in colors.

The principle of employing three plates screened by filters of red, yellow, and blue is retained. The manner in which the new camera exposes the three plates to the light from the lens is highly ingenious. The three sensitive plates are arranged for commercial use in a metal carrier similar to the ordinary film pack. The carrier is hinged at the bottom, and when placed in the camera and the slide withdrawn the front of the carrier faces to the bottom of the camera, carrying with it the front one of the three plates, two of the plates remaining upright in the back of the camera with their sensitive surfaces together. An amber-tinted glass held at 45 degrees with the horizontal and vertical plates reflects a portion of the rays from the lens upon the bottom plate and serves as a color filter to the rays passing through it to the plates in the rear. The last-mentioned rays strike the first of the two plates without hindrance, but before reaching the second they are further filtered by the coating of the forward plate. Thus each plate is suitably screened at the time of exposure and all are exposed at the same time. By a mechanical arrangement the amber-colored filter is moved aside and the bottom plate brought back into its original position in the holder.

The negatives are printed, one upon paper that makes a print in blue tones, the other two upon transparent bichromated film. The latter, after staining with dyes corresponding to the color of the screens through which their respective negatives were made, are then superposed over the blue print with the outlines in register, whereupon the subject is faithfully reproduced in all its colors. It is stated that the sheen of the satin dress, the soft and colorful shadows of filmy drapery, and the cobwebby bloom of the grape are all recorded faithfully by the camera and imparted to the prints.

THE PHYSICAL PHOTOMETER IN THEORY AND PRACTICE.*

(ADDITIONAL NOTE)

BY

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IN a recent issue of this JOURNAL the writer published[1] new quantitative data on the infra-red transmission of solutions containing cupric chloride, potassium dichromate, etc. The solution, which had been made up to give a transmission curve coinciding with the visibility of radiation curve of the average eye (when stimulated with light of a given intensity), was found to transmit a small amount of infra-red radiation, and the problem was to find the minimum thickness of a layer of clear water which would absorb substantially all the infra-red rays. The measurements in different parts of the spectrum dealt with quantities of radiation varying from 1 part in 30,000 to 1 part in 500 of the total radiation at a particular wave-length. That is to say, quantities of energy were measured with considerable precision which under ordinary conditions could not have been detected, or, if detected, would be considered negligible. However, for one particular application, viz., in a physical photometer, the quantities involved are not negligible, and one object of the paper was to present to the public for the third[2] and, what is hoped to be the last, time (for the writer) the conditions that must be fulfilled in order to absorb all the infra-red rays by means of this type of transmission screen.

After having worked out the details for eliminating the infra-red rays, evidently the logical thing to do was to place the luminosity solution and water cell in front of a thermopile and determine the performance of the combination as a physical photometer.

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* Communicated by the Author.

[1] This JOURNAL, September, 1915, p. 335.

[2] In two previous papers quantitative data were given: *Bull. Bureau of Standards*, 7, p. 655, 1911; 9, p. 110, 1912.

If certain difficulties can be overcome it is probable that, for certain kinds of investigations, the physical photometer will supersede the present method of photometry with its cumbersome and expensive equipment. Naturally there are prejudices to be overcome; and if an appeal is to be made to the illuminating engineer to try a new method of photometry, evidently all the available data (which at present are meagre) bearing upon the performance of the device should be presented. The second and principal reason for publishing the data was to show the performance of a physical photometer as found by one who had unexpectedly and reluctantly inquired into the merits of an instrument in which he had, up to that time, but little faith. The performance is admittedly favorable.

In presenting the data no attempt was made to properly accredit to the numerous predecessors the contributions made by each one; for the general discussion of the subject of physical photometry had already been ably presented by Dr. H. E. Ives,[3] whose contributions to the subject are well known and who is a strong advocate of this method of photometry.

In view of the difficulties which the writer has experienced in convincing others as to the performance of this device, in Table I are given data which were omitted in order to shorten the preceding paper. In that paper mention was made of these data which relate to the Ives luminosity solution diluted to one-fifth and used in a 5-cm. cell. No particular importance (other than the precision attained under various conditions, thus emphasizing the constancy of the behavior of the physical photometer as compared with the eye) is to be attached to these data, in view of the fact that the solution is not entirely opaque to infra-red radiation. However, it is sufficiently opaque to the infra-red so that the addition of an extra cell of water 1 cm. in thickness (see Table I, "Water Cell") has no appreciable effect upon the observations. This method of elimination, by adding absorption cells of water, does not, however, decide whether all the infra-red is eliminated. Only by a spectro-radiometric examination can this question be definitely determined. By a peculiar circumstance, the dilution of the luminosity solution seems to have changed the shape of its spectral transmission curve, so that when using it in determining

[3] Ives, *Trans. Illum. Eng. Soc.*, 10, p. 101, 1915.

the ratio of transmissions of certain blue and yellow solutions the value is B : Y = 1.001, which was the value sought by Ives and Kingsbury.

TABLE I.

Transmission of a yellow solution determined with a physical photometer having the luminosity solution diluted to 1/5 its concentration, contained in a 5-cm. cell. Tests were made with and without an additional cell of water 1 cm. in thickness placed in front of the thermopile.

Transmission: July 30, 1915. Surface thermopile, No. 56.

0.628 no water cell; temperature 29.2°.
0.623 no water cell.
0.624 with water cell.
0.625 no water cell.
0.628 no water cell.

M = 0.625

0.622 When using a 1-cm. cell of luminosity solution and correcting for 13.6 per cent. infra-red transmitted by the luminosity solution.

Ratio of transmission: Blue ÷ yellow solutions. July 30, 1915.

Using an additional 1 cm. cell of water	No water cell
0.997	1.000
1.000	1.000
1.003	1.000
0.994	
1.011	M = 1.000
1.006	
1.003	
M = 1.002	

1.004 July 29, using a linear thermopile.
0.999 July 28, using a linear thermopile: light is non-uniform.

Mean 1.00. at 29° C.

The inconsistency in the writer's previous paper in which a ratio of B : Y = 1.083 was obtained with a physical photometer is now explained. From the recent paper by Ives[4] it appears (1) that the original scheme of setting the transmissions of certain blue and the yellow solutions to equality, first with a physical photometer[5] and then testing them with a flicker photometer, was abandoned, and (2) that the blue and the yellow solutions, which gave equality of transmission by the flicker photometer, gave equal-

[4] Ives, this JOURNAL, October, 1915, p. 117. Ives and Kingsbury, *Phys. Rev.*, 7, p. 319, 1915.

[5] Ives and Kingsbury, *Trans. I. E. S.*, 10, p. 207, 1915.

ity of transmission with the physical photometer only after making up a new luminosity solution, having a transmission curve which is slightly shifted with respect to the luminosity curve of the average eye. In other words, the blue and the yellow solutions were first set to equality of transmission photometrically with a flicker photometer instead of radiometrically, as mentioned in the previous paper.

The transmission curve of the solution is obtained with a spectrophotometer by comparing lights of the same color. The luminosity curve of the eye is obtained with a flicker photometer by comparing the differently-colored lights with white light; and the question is: Does the luminosity curve of the eye, as determined with the equality-of-brightness photometer, really coincide with the one obtained with the flicker method, or is it shifted toward the red (for high intensities), as suspected?

While some of the data harmonize, others are discordant. The visibility of radiation curves themselves can hardly be called satisfactory from a radiometric point of view. One set of curves is based upon an energy evaluation in which the spectral energy curve is computed upon the basis that the source (which was a carbon incandescent lamp) is at a certain temperature. The light is passed through the spectrometer and corrections are made for the loss of light in the apparatus. The weak point in this method of investigation is the uncertainty of the temperature and, hence, the energy distribution of the source.

Some years ago an investigation was made, in this Bureau, of the spectral energy curve of an acetylene flame, set flat-wise and also edge-wise to the slit of (1) a mirror spectro-radiometer and (2) a spectro-radiometer with achromatic lenses having excellent optical corrections. From this it appears that one can use a spectro-radiometer having lenses to obtain luminosity curves by using a source having a known spectral energy curve and making corrections for losses in the apparatus. It will therefore be a simple matter for this Bureau to issue standard light sources having a certified spectral energy distribution, which can be used by experimenters throughout the country. In this way it will be possible to easily obtain visibility of radiation curves of a large number of observers and reduce the data to one common standard. In view of the great divergence in the observations, made by different observers, this method of energy evaluation seems to be

sufficiently refined for this particular investigation. However, after several years' deliberation upon this subject, it does not appear to be the proper method of procedure for investigations in general.

Obviously the logical procedure is to reduce stray light by using absorption screens, to use spectral lines whenever practicable, and to measure the stimulus at the observing slit. In view of the high sensitivity required to measure, radiometrically, the light stimulus of a 2-degree photometric field (recommended by Ives for the photometric comparisons), it will be better to observe the spectral energy curve by using the whole length of the slit and the full aperture of the lenses. For good lenses this same energy distribution will hold for a 2-mm. slit and a small aperture. The remaining measurements are also relative and may be made by reducing the intensities either by varying the slit opening, or by using crossed nicol prisms between the slit and the source. The second set of visibility-of-radiation curves now available was obtained by the method of measuring the energy at the observing slit. However, difficulties were experienced from unsteadiness in the radiometric apparatus, so that, while we have this much data[6] to be thankful for, more work must be done. In view of the fact that all the visibility of radiation observations by various observers are included in these two sets of energy evaluations, it is not surprising to find that the new, arbitrarily-made luminosity curve solution fits other experimental data better than the old solution described by Ives.

In addition to these perplexities, the psychologist aptly questions the propriety of using the flicker method as compared with the equality-of-brightness method of photometry, claiming that the two methods must give different values,[7] in view of the fact that the sensations aroused by lights differing in color value rise to their maximum brightness at different rates when using the flicker method. Has the physicist answered this question satisfactorily? The psychologist admits, of course, that in the flicker method the range in the settings is smaller than in the equality-of-brightness

[6] Nutting, *Trans. I. E. S.*, **9**, p. 633, 1914. In view of this fact it is relevant to add that this investigation and the mechanical equivalent of light were authorized four years ago and satisfactory progress has been made radiometrically. The main reason why the writer has held aloof from this problem for the past two years is because he has not been able to reconcile certain psychological facts with physical procedure.

[7] Farree and Rand, *Psychol. Rev.*, **22**, p. 110, 1915.

settings; but he maintains that the mean values will be different, and that the equality-of-brightness method is the one that gives the true value.

Evidently much remains to be done, in spite of the extensive work of Ives and Kingsbury in the production of a luminosity curve solution which satisfies all of their tests, and hence satisfies the requirements of a physical photometer having as essential parts (1) a thermopile and (2) a solution whose transmission curve coincides with the luminosity curve of the average eye.

It is desirable to reproduce Table II, which was published in the previous paper, in order to make a minor correction to one value which was copied erroneously in making up the table and to discuss more thoroughly the precision attained. It is to be noticed that in the first column of this table there are variations amounting to several per cent. in some of the determinations. Hence the criticism can be made that the device is not a precision instrument. It is to be emphasized, however, that this large variation is not due to an inherent fault in the instrument, but in the operation of the lamp. Neglecting the two "Poor sets" for the reasons previously given, the other determinations would have been more regular if the change in current from 0.3108 to 0.3258 ampère had been

TABLE II.

Giving the Ratios of Luminous Intensities, as Determined with a Physical Photometer, for Different Currents.

Ampères		
.3258 / .3108	.3404 / .3258	.3542 / .3404
1.356→	1.319	
	1.311	
←	1.311	
1.351		
1.344		
1.346→	1.313	
	1.314	
	1.313→	1.273
		1.280
		1.273
	←	1.274
1.363 }	Poor set.	
1.332 }		
1.337		
Mean values		
1.347	1.313	1.275

made in two steps instead of one, or if the higher intensity had been reduced by means of a sectored disk. This large change in current produced too great a change in the radiation emitted to be properly evaluated by the auxiliary galvanometer which was then being used. Columns 2 and 3 are to be considered for precision measurements which have a range of about 0.4 per cent.

In the October issue of this JOURNAL, under the title "The Establishment of Photometry on a Physical Basis," by H. E. Ives, the following statements are made:

"The practical physical photometer described under Section 4 is clearly the same instrument as that described by W. W. Coblentz in the September issue of this JOURNAL. Every detail of this photometer was worked out by the writer and Mr. E. F. Kingsbury. It was exhibited and described to Dr. Coblentz on the occasion of his two visits to our laboratory during the past year. It has been shown as well to numerous other visitors, for several of whom incandescent lamps and colored glasses have been measured. The device was described before the American Physical Society at its New York meeting, October 31, 1914, and the complete description has been in the hands of its journal, *The Physical Review*, since April. Its use forms one of the recommendations made by the writer to the Illuminating Engineering Society (*Trans. I. E. S.*, No. 4, p. 315, June 10, 1915) which are now under study at the Bureau of Standards on behalf of that society. H. E. I."

These remarks seem to imply that the visitor to Dr. Ives's laboratory was shown a device that was entirely new in every detail, and that the writer is guilty of publishing a description of this apparatus without giving Dr. Ives due credit. It is therefore of interest to recall that Houstoun[8] described a physical photometer consisting of a Rubens thermopile in front of which was placed a 3-cm. cell of copper sulphate and a 1-cm. cell of potassium bichromate of such concentrations as to give a transmission curve which coincided well with the luminosity curve of the eye. At a distance of 33 cm. from the thermopile he placed a 32-candlepower lamp, which he photometered at various voltages and simultaneously observed the galvanometer deflections. He obtained very good results (considering the lack of sensitivity of his radiometer), from which he concluded that the device could be used to

[8] Houstoun, *Proc. Roy. Soc. Lond.*, A 85, p. 275, 1911.

define our unit of light and as a basis for comparing lights of different color.

Having this work in mind, the subject of physical photometry was not new to the writer in May, 1914, when he first began designing and constructing thermopiles to be used by Dr. Ives and himself in a joint investigation of the mechanical equivalent of light. The only new thing that the writer could have obtained from Dr. Ives's laboratory, not already suggested by Houstoun and others, was the constituents of the luminosity solution, and, as his recent paper shows, the constituents of this solution are constantly being modified. The luminosity solution used in the joint investigation of the mechanical equivalent would naturally be used in a physical photometer, and the writer's paper (this JOURNAL, September, 1915) quoted the references to this and other papers by Ives and his collaborators.

It is to be noticed that our arrangements of a physical photometer are by no means similar. The one employed by the writer had a 1-cm. cell of clear water in front of the thermopile to absorb the radiations from the luminosity solution (which becomes warmed), thus preventing a shift of the zero reading of the galvanometer. A cell of clear water 2.5 cm. in thickness was placed in front of the luminosity solution to absorb the deep infra-red radiations and thus reduce the heating of the luminosity solution.

The illuminating engineer wants facts concerning the performance of the physical photometer when applied to measuring the light from incandescent lamps. In spite of all that has been written upon the subject of physical photometry, if we except Houstoun's measurements, my paper (this JOURNAL, September, 1915) gives the first crucial data on the performance of a physical photometer (consisting of a sensitive, quick-acting thermopile having in front of it a luminosity curve solution) in a test on incandescent lamps. Among other tests my paper gave the results of a comparison of a physical photometer with a visual (equality-of-brightness) photometer in which the test object was a standard incandescent lamp which had been photometered by various observers in various laboratories situated throughout the country. The recent paper by Ives and Kingsbury,[9] which deals with the physical and visual (flicker) photometry of certain blue and yellow

[9] Ives and Kingsbury, *Phys. Rev.*, 6, p. 319, 1915.

solutions, strengthens the view held from the beginning, that my contribution to the subject of physical photometry is a distinct practical application which had not been obtained by others and hence could not detract credit from them. As for my "assurance" that the concentration of the luminosity solution (used in the Mechanical Equivalent of Light) was sufficient to eliminate all the infra-red rays, it may be added, in conclusion, that this assurance was given orally, on the assumption that the same thickness of luminosity solution was being used as specified in my published papers [10] which gave the minimum concentration and the thickness of the cell required in order to eliminate all the infra-red when using a solution containing principally cupric chloride as an absorption screen.

WASHINGTON, November 15, 1915.

[10] *Bull. Bur. Standards*, **7**, p. 655, 1911; **9**, p. 110, 1912.

Motion Models. F. B. GILBRETH and L. M. GILBRETH. (*Proceedings of the American Association for the Advancement of Science*, December 27, 1915, to January 1, 1916.)—A tendency of this age is to think in parts rather than in wholes, in elements rather than in grouped elements. In the olden times both material things and human beings were invariably thought of as entities, wholes; but with closer thinking and the awakening of the scientific spirit of analysis, measurement, standardization, and synthesis has come the realization of the fact that the thing or person as a whole is often far less important than the fact that the thing or person is a group or community or combination of parts. The material thing is analyzed into its elements. The human being is thought of as a group of working members. The old-time operation is thought of as a combination of acts. Now, finally, a motion itself is thought of as a cycle or combination of elements of motion.

While units, methods, and devices of measurement, as applied to education, already exist, there has been a lack of means by which behavior could be accurately recorded, and of the necessary records which might be used as data for predicting behavior, and for outlining methods for obtaining future desired results. Motion models supply this lack. The motion model is a wire representation of the path of a motion in such visible and tangible form that it may be visualized and measured with accuracy, and from such measurement the laws underlying the behavior that caused and affected the motion, and the behavior that resulted from the motion, may be accurately determined.

Graphic Analysis of Building Vibrations. E. E. HALL. (*Electrical World*, vol. 66, No. 25, December 18, 1915.)—Vibrations transmitted to buildings from moving machinery are probably more disagreeable than dangerous in most cases. Outside of congested business districts ordinary vibrations receive little attention, but in installing machinery and foundations under metropolitan conditions the elimination of even slight vibrations is an insurance against possible future difficulties with abutting property owners. The absence of vibration-producing elements in steam turbo-generators is an advantage, often pointed out in this type of power plant, leading to marked economies in the costs of foundation work and even permitting at times attaching the units directly to the framing of the building.

With the very high speeds employed in turbo machinery, the greatest nicety of balance is essential to insure freedom from vibration, and the effects of inevitable imperfection of balance in commercial machines must be reckoned with. An analysis of the vibrations of a reinforced concrete building produced by a turbo-generator connected directly to the walls of the building was made by means of a portable vibration recorder of the type described in *Electrical World*, July 27, 1912, and *Engineering News*, August 1, 1912. The character and magnitude of the vibrations recorded in various parts of the building pointed to the desirability of mounting the prime movers low down and having the foundation of the prime movers separate from the walls of the building. In the type of mounting investigated not only are the vibrations increased but both sides of the suspended floor serve as a sounding-board, and the noise is greater than it would be if the turbo-generator were on the ground floor.

Substituting Copper for Aluminum. ANON. (*Electrical World*, vol. 66, No. 26, December 25, 1915.)—Arrangements have been made by the Rochester (N. Y.) Railway and Light Company to substitute No. 0 stranded copper wire for the 428,000-circ. mil. stranded aluminum conductors of a duplicate three-phase transmission line between Mortimer, N. Y., and the city of Rochester. This line brings 25-cycle 60,000-volt energy from the lines of the Niagara, Lockport, and Ontario Power Company at Mortimer to the city limits of Rochester, a distance of 2.2 miles. The transmission line was built in 1907 and designed to transmit 18,000 horse-power. The span lengths vary from 415 to 550 feet, with a calculated sag of 24.5 feet on the long span at 110°. The No. 0 stranded copper conductors will be strung on the same towers that are used by the aluminum lines, with about the same sag.

While the economic capacity of the two lines has been reduced by the change to about 12,000 horse-power, with the price of aluminum at 56 cents per pound and copper at 20 cents per pound, the basis on which the substitution was made, a net amount of $8400 has been realized from 63,000 pounds of aluminum through the change.

THE PRODUCTION OF LIGHT BY ANIMALS.*

BY

ULRIC DAHLGREN,

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PORIFERA AND COELENTERATA.

The sponges have been reported several times to show luminosity, particularly in their free embryonic condition. Mangold quotes three such instances, but an examination of the articles so quoted was far from convincing one that the cases have been carefully observed. While the matter is entirely probable, we still lack careful observation and study bringing forth positive evidence. The writer well remembers a tubful of dredgings from the bottom of the Bay of Naples in which sponges were mixed with many other forms. The whole mass glowed for hours after being brought into the laboratory, but a careful examination showed two facts: First, each luminous sponge, when looked at under the microscope, showed several kinds of luminous worms and protozoa distributed through its canals; second, these same sponges taken from other and cleaner bottoms showed no trace of light under the most favorable conditions and severest stimulations. It is not probable that sponges can light.

The coelenterata are one of our oldest and most widely distributed forms of animal life, and histologically and physiologically they have a remarkably uniform and characteristic tissue constitution. Among its characteristics may be mentioned a maximum of fluid in most of the cells, a remarkable general transparency, a tendency to form cell membrane and extracellular jelly, and a distributed physiology due to lack of an efficient medium of circulation.

Thus most of the bodily functions are carried out in simple epithelia, extending over large areas of surface and showing a marked absence of histological amplification (corrugation, evagination, and invagination). As a result of this there are almost no large or involved glands, whose operation and usefulness would be seriously impeded by the lack of circulatory channels and medium.

Since, however, a considerable number of functions, both

* Continued from page 125, January issue.

chemical and kinetic, are possessed by the animals, and since these functions must be distributed for the reasons mentioned above, we find that a section of any of the surface epithelia will show cells of many kinds, and serving corresponding varieties of functions, placed side by side and forming a comparatively complex tissue.

The function of light production is thus found only in the epithelial surfaces of coelenterates, and either distributed over the entire surface, or, as is most commonly the case, restricted to some moderately large area or areas. In no case so far described has any epithelial area been found to be devoted exclusively to light production, but the luminous cells have been scattered more or less thickly among cells of, usually, several other kinds.

The number of the luminous species of coelenterates is large and their distribution in the group is very general. Both the free swimming medusæ as well as the sessile forms, single as well as colonial, show light-producing members among their numbers. It will be convenient to describe a few of the decidedly luminous types in detail and then to draw some generalized conclusions concerning the whole group.

The medusa forms, or "jelly-fish," are well known, and among them is a species, *Pelagia noctiluca* (see Fig. 1), that is perhaps the best-known luminous coelenterate, especially if length of known acquaintance with mankind is counted for this. This large, beautiful species is a common form in the Mediterranean Sea. It is of typical jelly-fish form and swims by a series of rhythmic contraction of its "umbrella," as most of the other medusæ do.

The outer integument is partly colored red or brown. This color is present in various large patches and spots of irregular form separated from each other by narrow bands. The patches and spots are thickened and raised in contour, leaving the bands as depressions or valleys between them.

When this animal is swimming freely at home in the sea at night, or in an aquarium in the laboratory with plenty of fresh sea-water, it gives no light at all. A direct stimulus is necessary to make it show its light. This stimulus may be mechanical, chemical, or electrical. The most powerful stimulus is that with strong corrosive chemicals, as ammonia or some of the mineral acids. They should not be too strong, or the light cells will be killed too quickly.

Under these circumstances a great glow appears that seems to cover the outer surface of the umbrella and the outer surfaces of the larger arms and tentacles. The light is greenish in color and appears to cover the surfaces mentioned above in a rather irregular manner, being somewhat blotched and spotted, but so bright that the outlines of the irregularities cannot be identified. The light lasts for several minutes, dying out slowly (see Fig. 1).

It is with the mechanical stimulation that the light production can be better examined and studied, however. In this case, too,

FIG. 1.

Swimming individuals of *Pelagia noctiluca* as they appeared in the aquarium at Naples. Some had just been struck with a glass rod and were shining. (Original drawing by E. Grace White after descriptions by the writer.)

the animal is neither injured nor killed, and the degree of stimulation can be measured with reference to the amount of light produced.

A slight contact of the finger or a glass rod with the outer surface of the umbrella results in a spot of light at the point touched. This spot is local for only an instant, and then spreads out, but it may not cover the whole surface of the bell. The light appears in lines and streaks and occasionally in patches.

When the contact is made more violently the light is brighter and spreads over the whole umbrellar surface. If violent enough,

the luminosity does not spread, but appears on all the surface at the same time. In this case it is stimulated to appear by the mechanical jar that is communicated through the jelly.

A very noticeable feature of this lighting power is the fact that when one touches the illuminated surface, however gently, the luminous material clings to the fingers and shines on them almost as long as on the umbrellar surface. Thus we have proof that the material is discharged from the cellular tissues (the covering epithelium). If one strokes that surface with moderate firmness, while the animal is resting and not lighting, and withdraws the finger instantly before the light appears, no light will be seen on the fingers, proving that it has not yet been thrown out of the cells. And again, if the outer cells are scraped off, they will illuminate, but the tissues beneath them will remain dark.

These several experiments show that the light produced by the animal is the result of the bringing of a secretion, the luciferine, into contact with the free oxygen in the sea-water, when the luciferine is discharged from the cells that store it. These cells that secrete and store it are undoubtedly some or all of the simple epithelium that covers the outer surfaces of the umbrella and larger tentacles (see Fig. 2). It also seems that the discharge is the result of a nervous reaction following the stimulus, and that this impulse travels through the sub-epithelial plexus of nerves that is characteristic of the coelenterata. The light secretion is always mixed with a larger body of slime which is a mucin. The mucin comes from other and different cells than the luciferine, although it seems entirely probable that the luciferine cells are derived by differentiation from the mucin-secreting cells. In Fig. 2 are shown bits of the epithelium in question in which are drawn the various kinds of cells seen there.

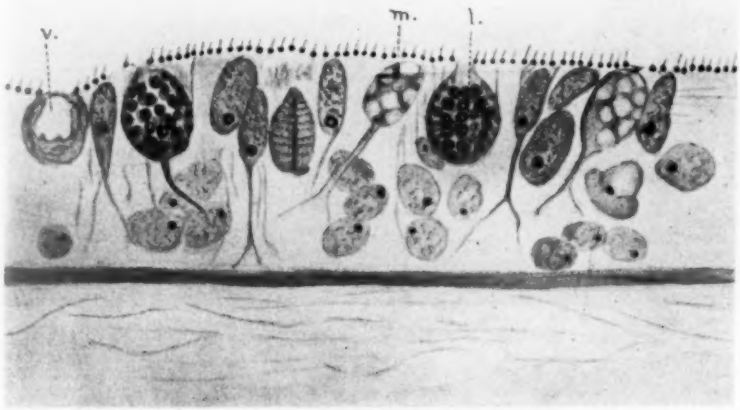
As luciferine is known to often come in the form of granules, it is probable that one kind of the granule-filled cells shown in this figure are the cells under discussion. Further exact work on both the physiology and the structure of this form is desirable. It is not known, among other things, if the production of light is temporarily inhibited by the action of sunlight in this species. Since the luciferine is apparently stored in a granular form, it would seem that this was not the case.

Many other medusa forms are known to give light, although none of them have been as closely studied as *Pelagia*. Dr. L. R.

Cary has told the writer about a cubomedusa, probably a species of *Charybdea,* which was observed in the waters of eastern Jamaica to give off a light from its four tentacles. The light was restricted mostly to these tentacles and was strongest on their ends. Its comparative weakness made it almost impossible to determine if the luminous material was discharged or was consumed in the cells. It appeared to be an intracellular combustion. This same is true of a number of other medusoid forms.

Among these other forms we find three methods of lighting as

FIG. 2.



Portion of a section of the ex-umbrellar surface of *Pelagia noctiluca,* showing several kinds of cells: *l.* luminous cells; *m.* mucin-secreting cells; *v.* empty cells from which the luciferine has been discharged. (Drawn from a section by E. Grace White.)

enumerated by Panceri. First, a number light in the same general manner that the form we have just been studying does, *Pelagia noctiluca.* Such forms are exemplified by *Pelagia phosphorea* and *Cumina moneta.*

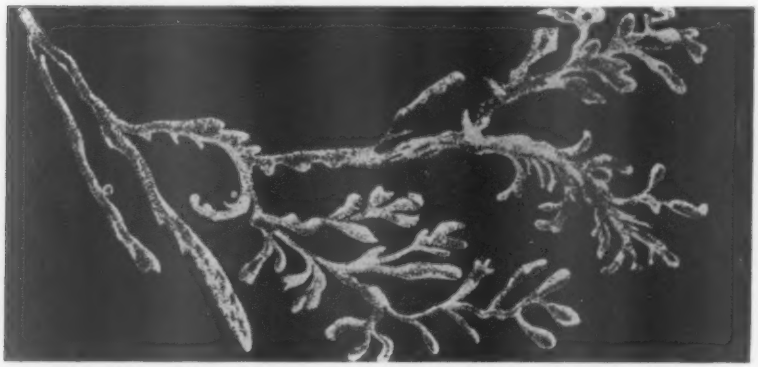
Another group light at the bases of the tentacles, such as *Thaumantias, Mesonema, Lyriope, Geryonia,* and many others. We lack exact work on these forms, except the article of Panceri, which was written in 1871.

The last group consists of several genera, as represented by *Dianœa appendiculata* and *Oceania pileata,* in which the light

comes from the ovaries and from some of the water vascular canals.

A careful study of the cells and tissues at the source of light in several sorts of these groups would undoubtedly enable one to analyze the different sorts of cells and differentiate out the general type of cell that is responsible for the light. According to Panceri, these cells are probably the granule-containing cells mentioned by the writer in connection with the light from *Pelagia*. Panceri worked by scraping the luminous parts, and noted these cells under the microscope in such scrapings. He considered the granules to

FIG. 3.



Drawing to illustrate the appearance of a sea-weed covered by a colony of the campanularian hydroid, *Campanula flexnosa*. The algæ appear to be luminous. Reduced twice (After Panceri.)

be droplets of fat, in which he was probably mistaken, as we now know that luciferine is not a fat.

The hydroids have been observed in several cases to be luminous, particularly several of the campanularia. Allman describes a luminous form, *Obelia dichotoma*, in which, upon stimulation, the whole colony lights and remains illuminated for several seconds. Panceri studied the form *Campanularia flexuosa* and showed that it lights in much the same way (Fig. 3). It often grows so thickly on algæ (on *Gelidium corneum* and on *Cystoseria cricoides*) that the algæ have been mistaken for luminous plants.

His studies of these forms under the low power of the microscope open up great possibilities as to a method of finding out more about the structures that do the lighting and their method

of lighting. When stimulated while under the microscope he observed that the light appeared as a series of fine dots or points, and he judged that each of these points represented a single cell or some vacuole in that cell. It may be possible that higher powers of the microscope will some time show us more about the lighting methods of coelenterates in this or in some similar form. Fig. 4 shows a branching stalk of one of these hydroids in the luminous state.

Panceri located these cells in the outer layer of the cœnosarc

FIG. 4.

Drawing to illustrate the appearance of a small twig of *Campanularia flexuosa* when lighting in the dark. Magnified twelve times. (After Panceri.)

or in the ectoderm of the animal, and he further showed that the impulse to light is carried by the nerve plexus just under the ectoderm and spreads out from any single point of stimulation in all directions. It even travels from one polyp to the rest, and with this delicate indicator it will be very easy to do some good work on the rate of the nerve impulse in these forms.

The jelly-fish belonging to many of the luminous hydroids are also luminous, but have not been closely studied.

Our next study will be that of light production as observed in the *ctenophores*, a large, homogeneous group of medusa-like forms, quite different in structure from the ordinary jelly-fishes, but well known to all. These creatures are surface-swimming forms found in all seas, and are of extreme transparency and delicacy. Some species have delicate pink and brown or even blue pigments, but most of them are colorless and can with difficulty be seen in the water. The solid content of the tissues is very small, and the creatures are so delicate in structure that even the motion of small wavelets will tear and dismember the bodies of some forms, such as *Mnemiopsis leidyi*, *Cestus veneris*, and others. A few of them are firmer in composition, such as *Pleurobrachia* and some *Beroe* species.

All the ctenophores have been known for a long time to be light producing. This fact is even well known among the vacationists and travellers, who, when the larger masses of light are seen in the surf or in a tide current or in a steamer's wake, say at once "jelly-fish," or, if they have received an education in which biology has played a part, "ctenophores."

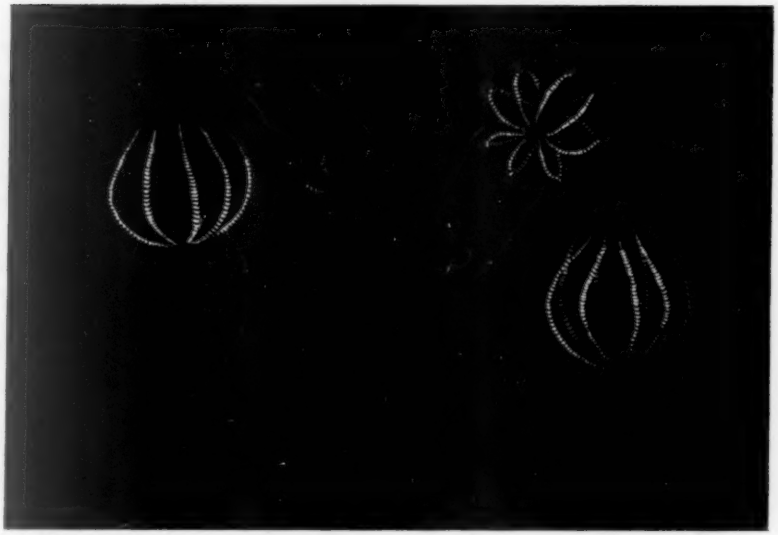
The ctenophores do not show light when at rest. Nor is the motion of their swimming plates accompanied by light. It may be remembered that Quatrefages tried to prove that in the protozoön, *Noctiluca*, the production of light was necessarily accompanied by the production of motion, and *vice versa*. We have positive proof, in studying the ctenophores, as Peters has shown, that the two modes of energy-release are not in any way connected as are the release of motion and heat, or motion and minute quantities of electricity.

The methods of lighting vary somewhat among these organisms. In the world's warmer waters, as seen by the writer in the Mediterranean and on the south Atlantic coast of North America, the light appears as a strong glow, almost a flash, lasting for one or two seconds after mechanical stimulation. The flash stops quite suddenly, and only a faint glow, or lines and spots of weak light, persists for a few seconds longer. In the colder waters of the north Atlantic the flash is longer, and, especially in small and young specimens up to two centimetres in size, the light is a strong, steady glow, lasting for as much as half a minute to a minute (see Fig. 5).

The effects of different temperatures upon the light production

in individual species are of interest and have been carefully studied by Amos Peters on *Mnemiopsis leidyi*. This summer form lives in a sea that in August, at Woods Hole, Mass., has a temperature near 21.5° C. A number of normal animals were first shown to be capable of strong luminosity, and then four of them were gradually cooled by cold water placed around the vessel that contained them, while four others were in a like manner warmed by warm water placed in contact with the dish in which they had been placed. As the cooling and heating progressed slowly the

FIG. 5.



Swimming individuals of the ctenophore *Pleurobrachia pileus* to show the appearance of the organisms as they swim about in the sea in the lighted and unlighted state. (Drawn by the author and E. Grace White from observation on the living animal.)

ctenophores were stroked from time to time in order to observe the effects of the treatments on their capacity for light production.

As the first lot became cooler it was seen that they produced less and less light until 12.5° C. was reached, when no more light was visible under any stimulation. Then the temperature was slowly raised and the power to illuminate slowly returned, showing that it was not death that had caused its inhibition.

This experiment was complemented in a most satisfactory way by the second lot warmed in their original sea-water. As the

temperature rose the light evoked by stroking with the glass rod became less and less brilliant, until at 37° C. no more was given off, even with quite violent stimulation. As this experiment was slowly returned to normal temperature, however, the light power returned until the phenomenon was quite normal again.

Several other experiments along these lines all showed that light production was at its best at the optimum temperature at which the animals usually lived. When the temperature was varied in either direction from this normal optimum, the light power diminished proportionally until it ceased entirely at temperatures, both above and below this optimum, that were not fatal to the creatures' existence.

The influence of daylight upon the luminosity of these forms was also very carefully studied by Peters. Already, in 1862, Allman and, in 1872, Panceri had observed that ctenophores (*Beroe*) would not show their light for some time after having been exposed to sunlight or to bright daylight. Peters further showed that, if they were mechanically stimulated during the exposure to sunlight or immediately after having been brought into the dark, they would recover the power slightly sooner. Thus he exposed two lots of the animals, A and B, to sunlight for about an hour and then brought them into the dark chamber. The lot A was agitated with a glass rod continuously upon being brought in, and began showing light in two and one-half minutes. The lot B was kept in quietness, and at the end of two and one-half minutes a stroke of the glass rod showed no luminous response. But in three minutes they also began to light. Thus the lot A acquired the power to light sooner as the result of a mechanical stimulation.

The two lots were then exposed to light again, A to direct sunlight for two minutes, and B to diffuse daylight. A was agitated as before, and B kept quiet. A lighted in one minute, while B retained the power.

After some minutes both were exposed to daylight, and when brought back into the dark A was agitated and B allowed to remain quiet. A lighted in one minute upon stimulation, and B in two minutes.

Peters thus showed that sunlight not only inhibits the luminosity, but also overcomes a previously-acquired power to light; also that mechanical stimulation accelerates the power to light. By a third experiment on new material he also showed that dif-

fused daylight can check luminosity and that mechanical agitation can accelerate its appearance.

Any periodicity in the lighting power of *Mnemiopsis* due to the alternation of day and night as such, and not to actual light or darkness, seems to be almost lacking. Peters did find a slight increase in light-producing power in night-time over daytime. Such periodicity has been studied in other coelenterates by several observers, as Brooks, Wilson, and Cary. The latter has very kindly allowed the writer to refer to some unpublished observations on the sand-living form of anemone, *Anthopleura cavernata*, found at Beaufort, N. C. Cary placed these creatures in vessels filled with sea-water, which was renewed by a pipe, so that at all times the animals were under the best living conditions. Ten animals were placed in each jar, and one jar was covered so as to be absolutely dark, while the other was left in the light. The normal behavior of these forms is to expand the tentacles at night and to contract them in the daytime. The polyps that were kept continuously in the dark expanded in the night and closed in the day as usual.

The experiment was then tried of bringing several arc lamps in the night-time directly over the jar that was kept open, as well as the one that was kept dark in the daytime. The strong light applied all night made no difference in the behavior of the creatures, which in both vessels kept their tentacles expanded and moving as though it were dark, which it was not.

A number of other physiological periodicities are known among the coelenterata that depend upon the alternation of day and night and are not affected by darkness and light alone. In the ctenophores, however, Peters showed that artificial light and darkness did control the egg-laying activities to a degree, as well as the power of light production.

Thus we see that the inhibition of light production in sunlight or daylight in the ctenophore is a reaction developed almost independently of the several forms of diurnal periodicity in coelenterata, one of which has just been described. It is evidently an economy that is of advantage to the organism, for it requires digested food and cell energy to produce light, and the light could not be of any possible use to the creature in the daytime, when it would not be visible.

Peters also attempted to fatigue the power by continuously

agitating healthy specimens in the dark chamber. Much light was at first given off, but it gradually grew weaker, and at the end of twenty minutes it was very weak, only interrupted gleams being given off. He found it impossible, however, to stop it entirely.

The writer found that at Naples two of the strong flashing kinds of ctenophores, *Cestus veneris* and *Beroe ovata*, gave a strong flash once or twice when continuously stroked with a rod, but that they were apparently exhausted in a few minutes, two or three at the most. At South Harpswell, Maine, in the cold waters of the Gulf of Maine, he observed some ctenophores, a species of *Mnemiopsis*, which were swimming about in floating eel-grass and other flotsam and jetsam in a corner where the wind had collected them. Here the ripples and wavelets were keeping them in a state of continual glow that lasted for over three hours without any weakening; they were still glowing as brightly as ever when the several observers left them at midnight, and they probably were able to keep it up all night.

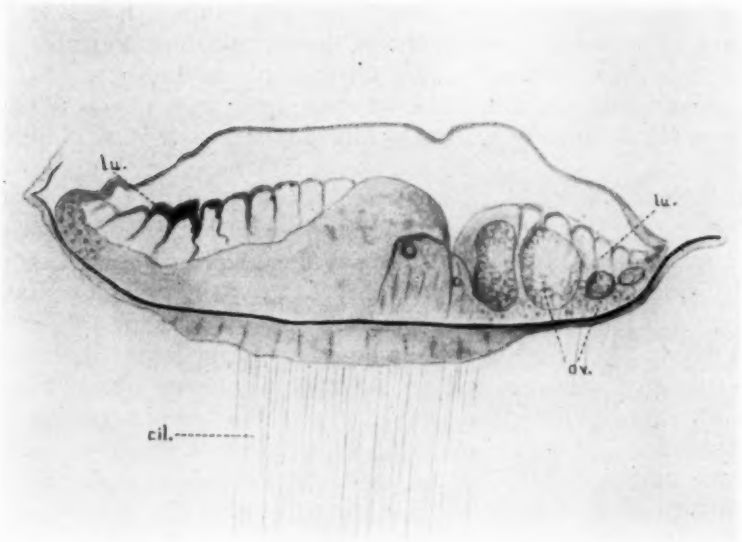
The assumption arrived at from these experiments and observations is that the ctenophores possess light-cells that, under the condition of daylight or any other bright light, do not secrete any luciferine at all, but when placed in darkness begin, after a short period, to secrete it and store it to a very limited degree. Only when mechanically stimulated do they allow it to come into contact with oxygen under conditions that show a light. The natural question now is, Do they thus use it by an intercellular consumption, or, like the jelly-fish *Pelagia* mentioned before, do they cast it out of the cells where it will come into contact with a supply of oxygen? This question can be decided only by a better understanding of the location and structure of the light-cells and their surrounding tissues, and what little of this is known will now be explained.

When a ctenophore lights the glow appears to come from the eight rows of paddles that band its body in the same direction as the stripes on a squash or watermelon. If the finger be rubbed on these glowing lines a certain amount of slime will come off on them, but no luminous material. The first thought is that here we have to do with a form of internal luminosity, the opposite from that condition found in *Pelagia*.

Several observers, however, have watched the lighting very carefully and have seen it apparently come from a line inside of

the paddle plates, and have identified this line as the outer wall of the water vascular tube which is an invagination from the digestive tract. The water vascular tube is lined with an epithelium that has undergone a high degree of differentiation, especially on its wall nearest the paddle plate. Fig. 6 is a sketch of a section of one of these tubes, with its surrounding tissues, to show the general location. This differentiation consists of a modification on one side of the outer wall into a germinal epithelium-producing

FIG. 6.



Low-power sketch of a section of one of the water vascular canals of *Pleurobrachia pileus*: *ov.* ovary; *t.* testis; *cil*, cilia on paddle plate; *lu*, layer of luminous cells covering ovary and testis. (Drawn from a section by E. Grace White.)

ova, and on the other side of a germinal epithelium-producing sperm.

Between the two the epithelium is thickened into a mass of vacuolated cells that appear to spread out on each side over the ova and over the sperm to make a sort of covering for them. It is these cells, with their highly-vacuolated and glandular nature, that have been suspected of being the luciferine-producing cells.

Certainly the light comes from this region; equally surely it does not emanate from the ova or sperm, for both Allman and Peters experimented carefully with this subject, and the latter

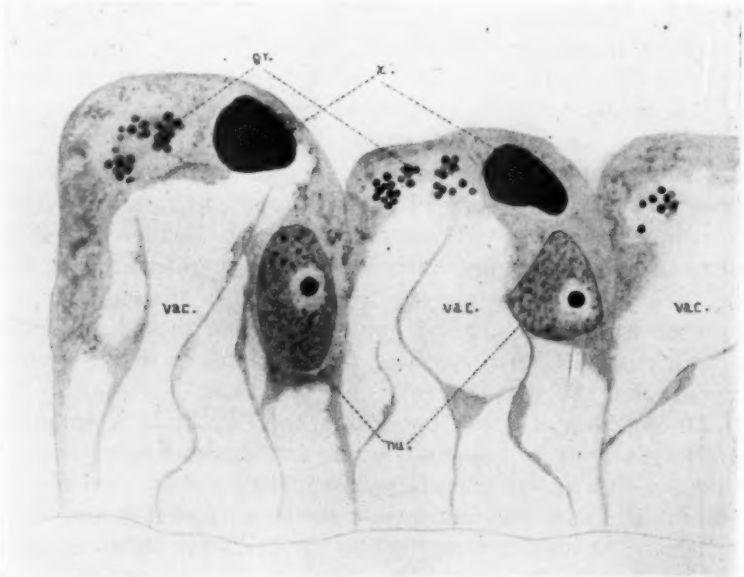
showed that the new-laid egg did not light. This leaves two other kinds of cells—the vacuolated cells above mentioned, and certain granulated cells lying at the base of the ovarian epithelium. These latter are easily disposed of by two observations. They cannot be the light-cells, because they stain with osmic acid and are of a distinctly fatty nature. Also, as Dr. E. G. Conklin has told the writer, they are characteristic of the female gonads in several other forms of animals in which no light is produced.

The vacuolated cells found distad of both ovary and testis, then, seem to remain as the most probable source of the light. The vacuoles probably represent the spaces in which some fluid form of luciferine is secreted and stored rather temporarily, and only when the creature is in a fairly complete darkness. Weak evening light, starlight, and even moonlight, do not seem to have the power to inhibit the light production, although Panceri thinks they do.

The cells are of a characteristic shape, as may be seen in the drawing (Fig. 7), and the nucleus is very large, and from its structure appears to be the nucleus of a secretory cell. Certain inclusions in the outer part of the cell (Fig. 7, *in*) might be luciferine, but it seems more probable that the vacuoles are the spaces in which, among other fluids, a liquid luciferine is stored between the time of secretion and of combustion. Peters's experiments with regard to the influence of daylight show one interesting circumstance: the ctenophores will not luminesce in sunshine, nor for some minutes after. If the light for the animal is due to the combustion of a secretion, this seems to mean that the secretory process does not begin until after the animal has been brought into darkness. Again, the secreted material is not consumed until a stimulus (mechanical in this case) has been applied. The flash will not be any brighter or longer even after many hours than it will after the first half hour, showing that only a certain amount of the material is ever stored up. More material is soon stored after a flash is given, and we find it difficult in *Mnemiopsis* to force the animal by repeated agitation to use up its material faster than it can be made. Indeed, Peters showed that this was impossible, although it was greatly weakened at the end of twenty minutes. On the other hand, the writer found that certain warm-water forms at Naples flashed more strongly and were more quickly and completely exhausted.

If now we allow sunlight to fall for a half hour or even less on a healthy ctenophore that has been resting quietly in the dark for a few hours and then return it to the dark and at once attempt to stimulate it to lighting, we would get no light, although we have assumed that it has stored up enough luciferine to do so. One of two conditions must be assumed to explain this fact. One is that the luciferine already present has been resorbed or has changed into non-luminous material, or we must assume that the

FIG. 7.



Two luminous cells from above section, much enlarged to show details of structures: *nu.* nuclei; *vac.* vacuoles; *gr.* granules; *x.* unknown body always found next to the granules in distal part of the cell. (Drawn by E. Grace White.)

sunlight inhibits not the production of luciferine, but instead it inhibits the nerve action that initiates its use; for it is evidently controlled by a nerve action.

Careful study of these probable luciferine-secreting cells seems to show that the combustion is really intracellular. None of the cells seems to have broken nor to have discharged its contents in any way. Also, the large size and segregation of the different (at least three) kinds of inclusions would indicate that the work was done internally. Even in case the secretion of the light-cells

was discharged into the water vascular canal, while we would technically have a form of external combustion, we would actually have the process taking place in a cavity of the animal's body and would not be able to rub off the luminous material on the fingers, as in the case of *Pelagia*.

The eggs of the ctenophores have often been reported to be luminous by earlier writers, but both Peters and the writer have attempted to show this and found it not to be the case. Peters experimented with the developing eggs and found that early segmentation stages would give a single small flash when the dish containing them was jarred, and this was before any cilia had made their appearance. Such a single flash seemed to exhaust the power in these young animals. When the gastrula stage had been reached it was possible to get several tiny sparks in succession, and from then on the power grew.

Mutilation showed but little except that there was no general nerve-centre in control of all the luminous apparatus. When a ctenophore is cut in two or four or much smaller pieces the power to light is retained until the portion is so small as to bear less than four paddle plates. When smaller than this it was observed to be incapable of luminosity, even though still alive and with its one, two, or three paddle plates in active motion, showing that it was still alive.

Among the Actinozoa, one group, the Pennatulidæ, are noted for their strong luminosity. These organisms are colonies of individuals arranged in rows on a feathering stalk (see Fig. 8) and provided with a common muscular foot which digs and moves in the sand or mud and carries the whole colony about to favorable locations. Sea-pens or sea-feathers they have been called, and the resemblance can easily be seen in the figure.

The luminosity of these creatures has been mentioned or briefly described by Gesner in 1555, Imperati in 1672, and in later times by Shaw, Grant, Ellis, Tilesius, and Blainville. Spallanzani, in 1798, told how the sea-pen shone when it was shaken, and how the light came from the single polyps on its branching arms. In his thorough, scientific way he even showed that the luminosity was in the discharged slime from the animal's body. Rapp, in 1829, again called attention to the fact that the luminous material was in a slime that was discharged from the body surface of the polyps and which stuck to and shone on the fingers of a hand that touched the creature. Della Chiaje described how the light

progressed from either tip to base or base to tip, according to which point first received the stimulus.

FIG. 8.

Drawing to illustrate the appearance of *Pennatula phosphorea* when in its habitat and shining. (Drawn by Bruce Horsfall from descriptions by the author.)

Panceri, who has told us so much about the luminosity of animals, also worked on the Pennatulids and studied their reac-

tions while lighting. He found that the luminous tissue consisted of masses of cells placed in the forms of cords or bands on the outer wall of the stomach and reaching into papillæ surrounding the mouth. This seems to be an unusual position in any coelenterate, and should be studied by more modern methods in conjunction with a study of those jelly-fish that have the light tissue situated on the ovaries.

There are eight of these cords placed between the mesenteries, and they evidently have intimate nervous connections with each other as well as with the general nervous system of the colony. The cells of these cords contain, according to Panceri, numerous fat droplets, which we must again interpret as granules of luciferine.

As already mentioned, Panceri also showed that the lighting proceeded from any point of stimulation in all directions. If one injured or touched the base, a line of light travelled up and spread out on each row of polyps as it advanced up the main stem. The same was true of any stimulation of the tip of the feather-like colony. Again, if the end of any such branch was stimulated the lighting proceeds down that row to the stem and then travels up and down the stem and out on the other branches in the same way. The speed of these waves or nerve impulse is about 20 seconds for one metre. Wagner has reported a more general luminosity on the stem and foot of Pennatula which others deny.

The light produced by the pennatulids is quite different in most cases from that shown by the jelly-fishes and hydroids. While that of the latter is usually greenish and white, and while the ctenophores show a brilliant emerald-green light, the different reports concerning the various kinds of pennatulids show that their light ranges from " silvery-white " to lilac or violet.

Wyville Thompson dredged many large specimens of *Pavonaria quadrangularis* from deep waters off the coasts of the British Isles. Often it was dark when the dredge came up and over the side of the ship, and he describes the " pale lilac " light shown by these animals as they came up through the water and were thrown on the deck. This observer had the additional advantage that usually there were many specimens of an ophiurian, *Ophiacanthia spinulosa*, in the dredge together with these pennatulids, and the ophiurians were shining with their green light, thus giving him the opportunity of an actual comparison, a most necessary condi-

tion when matching or describing colors, as all know. The light of the pennatulids was further compared in its color to the flame of cyanogen gas, and it was a constant light which most probably had been shining for some time, as the animals were torn from the bottom and hauled up through the hundreds of feet of intervening water.

Panceri describes the light of another pennatulid, *Cavernula pusilla*, as a lively blue. Agassiz describes the light of our American shallow-water *Renilla* as golden-green.

The siphonophore medusæ are reported to give a light by both Panceri and Giglioli. The latter mentions the genera *Praya*, *Diphyes*, *Abyla*, and *Eudoxia*. Tilesius includes *Physalia* among the forms that illuminate, but others have denied it. No careful work has been done on these forms, whose delicacy and rarity make them difficult to work on, especially at night. The color of the light has been mentioned as of various unusual shades, as red and violet. The colors of the weaker exhibitions of light are sometimes hard to distinguish, and the writer has observed in many luminous animals that the first weak flashes that precede a stronger exhibition are of a deep violet color.

Of other coelenterates we have mere statements or casual observations which show that gorgonians and corals are luminous. In some few species of Antipatherians as well as a species of *Mopsea* and of *Isis* a luminosity was observed by De Folin. It was very bright and one could read the finest print at a distance of eighteen feet from a tub full of dredgings in which these forms were abundant. Monaco saw several forms of corals that were luminous.

In general we may say that a very large number of coelenterates show light, that it is usually weak in comparison to that of the stronger light shown by some other creatures, and that it shows variations as to position of luminous tissues and method of bringing the luciferine into contact with the reagents that cause it to illuminate.

(To be continued.)

Higher Steam Pressures. R. CRAMER. (*Proceedings of The American Society of Mechanical Engineers*, December 7 to 10, 1915.)—Since the laws of thermodynamics have been recognized by engineers as a sure guide to improvement of heat engine economy, there has existed a tendency to increase the temperature range of

the working fluid; that is, to increase the temperature at which the working medium absorbs heat and lower the temperature at which it rejects heat. This has led, in steam engine practice, to the recognition of well-defined limits imposed by operating conditions; namely, a maximum temperature of 600° F. and a minimum of 80° F., corresponding to a pressure of one-half pound per square inch, or 29 inches of vacuum.

In the best present-day practice the maximum steam pressure is 200 pounds per square inch, absolute, with a superheat of 200° F. The corresponding temperature of evaporation is 382° F., and the bulk of the heat is absorbed at a temperature 200° F. below the maximum. It seems reasonable to expect that the approximation to the ideal Carnot cycle, and simultaneously the economy, would be improved by using higher pressure and less superheat; that is, by increasing the temperature at which the bulk of the heat is absorbed without increasing the maximum temperature. Steam pressures might be increased to 600 pounds per square inch without using temperatures higher than those employed in modern practice, and the difficulties encountered by the designer would not be formidable and would be more easily met than those of some types of explosion engines which have been successfully designed.

Parallel Packing of Nails by Electricity. ANON. (*Scientific American*, vol. cxiv, No. 2, January 8, 1916.)—Heretofore no attention has been paid to any order in the packing of nails in the container; they have been dropped loosely in the keg, the pieces locking and interlocking in a hopeless tangle. Now, however, with the aid of a special machine, nails can be nicely and accurately arranged in a box parallel to each other, so that their removal by hand is a simple matter. The greatest advantage of the new method is that the nails systematically laid in a box will occupy little more than half the space required when they are dropped in the keg. The boxes filled by the machine have a capacity of fifty pounds and are no larger than a five-pound confectionery box.

The machine is of German origin and is just being introduced into this country. Its operation is based upon the principle that linear iron articles when brought into a magnetic field will automatically take a position parallel to the lines of force. The machine consists essentially of the electric paralleling mechanism, a feeding trough and shaking device. By means of the latter the nails glide gradually into the paralleling mechanism and, while still falling, are drawn in the direction of the lines of force. The nails are passed into a tray fixed between two magnetic poles, and at intervals the tray is pressed downwards and the contents emptied into boxes. With but little adjustment the machine may be made to handle any size of nail. The paralleling mechanism uses direct current at 110 or 220 volts.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

THE "CENTRE OF GRAVITY" AND "EFFECTIVE WAVE-LENGTH" OF TRANSMISSION OF PYROMETER COLOR SCREENS, AND THE EXTRAPOLATION OF THE HIGH TEMPERATURE SCALE.[1]

By Paul D. Foote.

[ABSTRACT.]

An equation has been derived representing, as a function of the temperature of the black-body source sighted upon, the "effective wave-length" of any pyrometer color screen or system of color screens, or of color screens used in combination with sector disk, nicol prisms, or absorption screens. Attention is called to the difference between the "effective wave-length" and the "centre of gravity" of the luminosity curve, as the so-called centre of gravity of the color screen has been in the past sometimes considered the true effective wave-length. When an absorption glass, nicol prisms, or sector disk are used with a pyrometer employing light which is not strictly monochromatic, such as the Holborn Kurlbaum instrument, for the object of reducing the brightness of the sources sighted upon, the relation between the true temperature ϑ and the measured temperature S is of the form $1/\vartheta - 1/S = A$, where A has been heretofore considered a constant. Actually, it is shown, A is an important function of the temperature of the source. The consideration of A as a constant may introduce errors as great as 40° or 50° at 3500°if the absorption device is calibrated in the usual manner. When two or more absorption glasses are used together, it is not permissible to assume that the value of A for the entire system is equal to the sum of the values of A for the glasses used separately. It is shown that the combination of a sector disk and absorption glass gives a value of A which is practically independent of ϑ.

* Communicated by the Director.

[1] Scientific Paper No. 260.

MAGNETIC TESTING.*

[ABSTRACT.]

THIS circular deals with the fundamental magnetic quantities, the data required for ordinary engineering purposes, the scope and methods of magnetic testing at the Bureau of Standards, typical data of magnetic materials, and with empirical formulas connecting the magnetic quantities ordinarily used. It also gives magnetic constants for the elements, as well as for some of the more important compounds.

The fundamental magnetic quantities are those commonly used in engineering or technical work. Definitions are given and the question is considered as to what extent the complete magnetic data must be given to define the magnetic characteristics of a material.

The scope of the work of the Bureau in magnetic testing is outlined, giving the size of test-pieces required and the data ordinarily required for various engineering needs. The methods of testing are described in some detail, calling attention to the difficulties and sources of error and the importance of proper sampling.

Typical data and curves are given for representative materials in commercial use. These include materials for permanent magnets, electromagnets, armatures, transformer cores, etc. A table is also given showing the magnetic susceptibility of the chemical elements, together with a few of the more important compounds.

Considerable attention is given to an analysis of some of the empirical formulas which express the relations between the various magnetic quantities. These formulas are useful in indicating the behavior that may be expected of materials under conditions other than those under which they have been tested.

Finally a list of the Bureau publications on magnetic subjects is given. These publications are issued in pamphlet form and will be sent upon request.

* Circular No. 17.

STANDARD TABLES FOR PETROLEUM OILS.*

SAMPLES of both crude and refined petroleum were collected from the different oil fields of the United States, and their densities measured at temperatures between 0° and 50° C. On a part of the samples the measurements were made up to 85° C.

The investigation has shown that for practical purposes the rate of expansion of petroleum oil is a function of density and temperature only.

From the data obtained extensive tables have been prepared for reducing to the standard temperature the values of specific gravity, volume, and Baumé degrees observed at other temperatures. Tables have also been prepared for showing the relation between specific gravity, Baumé degrees, and pounds per gallon.

THE DETERMINATION OF BARIUM CARBONATE AND BARIUM SULPHATE IN VULCANIZED RUBBER GOODS.†

By John B. Tuttle,
Associate Chemist.

[ABSTRACT.]

SPECIFICATIONS for purchasing rubber goods frequently permit the use of barytes (barium sulphate) as a mineral filler without having the sulphur which it contains count as part of the specified total sulphur. In such cases the barium sulphate must be determined in order to properly correct the total sulphur.

When barium sulphate only is used, the amount present is readily ascertained by determining the total amount of barium present. If barium carbonate is used, it is necessary to separate the two salts. By means of tests made on compounds of known composition prepared at the Bureau of Standards, a method has been devised which permits the quantitative determination of barium carbonate in the presence of either lead sulphate or barium sulphate, the two sulphates most commonly used in rubber goods. The accuracy of the determination is satisfactory for all practical purposes.

* Circular No. 57.

† Technologic Paper No. 64.

SOME QUALITATIVE TESTS FOR GUM ARABIC AND ITS QUANTITATIVE DETERMINATION.*

By C. E. Waters and J. B. Tuttle.

[ABSTRACT.]

As might be expected from their chemical nature, the gums do not readily lend themselves to reactions of a definite qualitative or quantitative value. The object of this paper is to bring together the most important methods that have been published, with more or less discussion of each, and to present a new procedure for the determination of gum arabic. Reference is made to numerous attempts to find qualitative methods that would be at least as satisfactory as those which were not new. It was found, however, that basic lead acetate gives the most characteristic reaction. Mixtures of neutral ferric chloride and alcohol, and of copper sulphate and sodium hydroxide are of value as confirmatory tests. Dextrin and gum ghatti, which is in many respects similar to gum arabic, behave toward these reagents quite differently from the latter gum and from one another.

Heating with potassium hydroxide, color reactions with phenols and a considerable variety of other reagents were found to give indications of no value.

For the quantitative estimation of gum arabic there have been suggested several methods, to all of which some objection can be made. Ferric chloride with calcium or sodium carbonate, lead acetate, alcohol, and copper sulphate with an alkali have been proposed as precipitants. Of these the reagents that yield precipitates easy to handle are not specific for gum arabic. Other methods depending on hydrolysis or oxidation have been found wanting.

After numerous trials of copper sulphate and alkali, as well as of modifications of Fehling's solution, the authors found that satisfactory quantitative results are obtained by the following procedure. Dissolve 50 grammes of copper acetate in water, add an excess of ammonia, and dilute to 1000 c.c., using water and alcohol in such proportions that the final solution contains 50 per cent. of alcohol. For each determination, 50 c.c. of a solution containing about 0.25 gramme of gum is pipetted into a 250-c.c. beaker, an equal volume of alcohol is then added, and finally 25 c.c. of the copper reagent, with constant stirring. The

* Technologic Paper No. 67.

precipitate is allowed to settle, is filtered on a tarred paper, washed with 50 per cent. alcohol containing ammonia, then with 75 per cent., and finally 95 per cent. alcohol. It is then dried to constant weight at 105°, ignited in a porcelain crucible, and the ash weighed. The amount of ash deducted from the weight of the original precipitate gives the "net gum arabic." The amount of moisture in the gum originally taken for analysis must be allowed for. This is determined by drying in a stream of hydrogen at 105°. The percentages of gum found in a series of 18 determinations averaged 99.5 per cent., the extreme values being 96.6 and 103.3 per cent.

THE DETECTION OF RESIN IN DRIER.*

By E. W. Boughton.

[ABSTRACT.]

ALTHOUGH the distinction is not always recognized in the paint trade, oil driers differ from japan driers in that the former contain no resin. The introduction of any considerable amount of rosin into a paint by the addition of a drier containing rosin makes the paint unsuitable for outside work, but it is improbable that the substitution of a japan drier, free from rosin, for an oil drier, or *vice versa*, makes any noticeable difference in paint films, if the drier is added judiciously. Resin may be detected in drier by the following methods: (1) Test for rosin by the Liebermann and Storch test. (2) Treat 0.2 gramme of the mixture of unsaponifiable matter, fatty acids, and resin acids, obtained from the drier, with 5 c.c. of 97 per cent. alcohol. A marked turbidity or a deposit of insoluble matter shows the presence of resin, but rosin in small amounts of Kauri cannot be detected in this way. (3) Treat a one-gramme portion of the mixture of fatty acids, resin acids, and unsaponifiable matter with absolute alcohol and concentrated sulphuric acid (Wolff's method), and by titration with 0.25 N alkali determine the acid number (mg. of KOH per gramme of the mixture of unsaponifiable matter and acids taken) due to unesterified acids. An acid number of over 10 shows the presence of resin. By this procedure resin can be detected when the amount is at least 6 per cent. of the ash-free non-volatile portion of the drier.

* Technologic Paper No. 66.

Platinum Substitutes in Lamp Making. ANON. (*The Journal of Industrial and Engineering Chemistry*, vol. 8, No. 1, January, 1916.)—An incandescent lamp must be hermetically sealed and yet must have current led through its walls to the filament. From the beginning this has been effected by sealing two platinum wires through the red-hot glass, all other methods having been quickly discarded. Lately, however, sundry substitutes for all-platinum seals invented by Byron E. Eldred have, to all intents and purposes, displaced the use of platinum. These seals have proved not only as good as platinum, but better.

In sealing a wire through glass two things come into play, one being the adhesion of the metal and the glass, or what is termed the "wetting" of the metal by the glass, and the other the relative expansion and contraction of the metal and the glass. Softened or fluid glass "wets" platinum readily. This may be in part due to the specific physical affinity of the molecules of glass for the molecules of platinum, and may in part be due to the fact that the platinum maintains a metallic surface during the sealing operation.

The expansion of glass, however, is somewhat more than platinum, even with the soft glasses which are often used for lamps. The difference is not great, but it exists. The net result in cooling a platinum glass seal from a high temperature to a lower temperature is that the platinum tends to shrink away from the glass. This shrinkage is not great, but it is responsible for a little strain—a strain which is resisted by the adhesion of the glass and the platinum. Mr. Eldred conceived the idea of doing away with this condition of tension by making a wire whose expansion was a little less, but not much less, than that of the glass to which it was to be sealed. With a wire of this kind, on sealing and cooling, the glass shrinks down on the wire and there is a little compression in the seal. The amount of this compression must not be great, since otherwise dangerous strains might exist, but a little compression there should be. He devised a type of wire having a core of nickel-steel of very low rate of expansion, a jacket of copper on the core, and a further jacket of platinum on this copper sheath. The composition of the nickel-steel was so chosen that its own expansion, averaged with that of the copper and the platinum, gave the wire, as a whole, a little less expansion than that of the glass, so that, in sealing, the desired shrink-on effect or compression seal could be attained. The function of the copper in this combination was not only to give a greater electric conductivity—something much needed in these small-gauge leading-in wires—but also to make more regular the expansion of the nickel-steel. While nickel-iron alloys can be made to have any expansion within a certain range that may be desired, this expansion is not regular through the range of temperature incident to the sealing-in. The copper serves to make this curve of expansion more regular.

THE FRANKLIN INSTITUTE.

(Proceedings of the Stated Meeting held Wednesday, January 19, 1916.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 19, 1916.

PRESIDENT DR. WALTON CLARK *in the Chair.*

Additions to membership since last report, 36.

Mr. G. H. Clamer, Chairman of the Committee on Science and the Arts, reported the condition of the work of the committee.

The tellers of election, Messrs. Jennings, Colvin, and Picolet, submitted the report of the ballots cast for President, Vice-Presidents, Treasurer, and members of the Board of Managers, and the following gentlemen were declared duly elected to the respective offices:

Walton Clark, President (to serve one year).

Henry Howson, Vice-President (to serve three years).

Louis E. Levy, Vice-President (to serve two years).

Cyrus Borgner, Treasurer (to serve one year).

Francis T. Chambers, W. C. L. Eglin, Alfred C. Harrison, Charles A. Hexamer, Robert W. Lesley, Marshall S. Morgan, Robert S. Perry, E. H. Sanborn, Managers (to serve three years).

Kern Dodge, Manager (to serve two years).

William C. Wetherill, Manager (to serve one year).

The President presented a statement of the work of the Institute for the fiscal year ending September 30, 1915, with the Reports of the various Committees of the Institute and Board of Managers (appended).

Dr. Melville E. Stone, General Manager, The Associated Press, New York City, was introduced and addressed the meeting on the subject of "Supplying the World with News."

He described the early attempts at news-gathering, beginning with those of Samuel Topliff, of Boston, Mass., in 1812, and followed later by the New York Associated Press, the Western Associated Press, and finally by The Associated Press with its nine hundred members. Mention was made of the various foreign agencies which coöperate with The Associated Press in obtaining the world's news for the daily press. The methods of collecting such news and distributing it throughout the United States were fully described, and incidents were related illustrative of the work of the organization and the rapidity with which news items are obtained and transmitted from various parts of the world. After a discussion, in which Messrs. Henderson, Bond, Clark, Sellers, Levy, and others took part, the thanks of the meeting were extended to Dr. Stone.

Adjourned.

R. B. OWENS,
Secretary.

PRESIDENT'S REPORT AND REPORTS OF THE COMMITTEES OF THE INSTITUTE AND THE COMMITTEES OF ITS BOARD OF MANAGERS

FOR THE FISCAL YEAR ENDING SEPTEMBER 30, 1915

REPORT OF THE PRESIDENT

To the Members of The Franklin Institute:

In presenting this report under authority of your Board, I make the fact that just a decade of time has elapsed since I first had the honor of speaking to a meeting of The Franklin Institute my excuse for prefacing the more formal portion of the report with some of the thoughts on the Institute and its past, which naturally come to me at this time.

Ten years ago to-night for the first time I had occasion to thank the membership of The Franklin Institute for the honor of election to the office of President. Each third Wednesday in January, through the intervening years, I again have had reason to thank you for your expression of confidence, and have felt more deeply the honor conferred upon me, and more deeply the responsibility that the honor brought with it.

Naturally, at the end of the decade my mind runs backward over the intervening years. The ten years that have elapsed since I first occupied this chair have seen profound changes in the Institute and in the personnel of its management. To-night I, as a member of the Institute, mourn—as must you—the loss of many good friends; men whose contributions to the work of the Institute were valuable and timely; men, some of them, who had grown old in the service of the Institute, and whose going has added to the difficulties of maintaining the standards they had helped to establish. Few indeed of the men who were carrying on the work ten years ago are now with us. Of the twenty-four members of the present Board of Managers, whose report this is, but five were members a decade ago. To-day there is no living ex-president of The Franklin Institute. John Birkinbine, for ten years the president and throughout his life an hereditary friend of the Institute, has died since our last annual meeting. We miss him and we mourn him.

There is one living ex-secretary of The Franklin Institute—Dr. Isaac Norris, Jr., who served three years, thirty-five years ago. Dr. Norris is now the oldest member of the Board, in point of service. Dr. William H. Wahl, that talented gentleman who knew not when to rest if there was any work for the Institute to be promoted, died in 1909 after thirty years' service as secretary. Following Dr. Wahl's retirement from the position of secretary—a retirement forced by ill-health—James Christie undertook to fill in the gap between the retirement of Dr. Wahl and the selection of a permanent successor. Mr. Christie died in 1911, and there are few men whose decease the Institute has had more occasion to mourn.

There is no living ex-actuary of The Franklin Institute. Herbert L. Heyl, who was the actuary at the beginning of the period we are discussing, and

who died in 1908, was temporarily succeeded by James Christie, who undertook the duties for a brief period, giving his services here, as in the office of secretary, without compensation.

There is no living ex-treasurer of The Franklin Institute. The distinguished Samuel Sartain, who was treasurer from 1883 to 1906, died in the latter year, and was succeeded for a short period by Dr. Wahl, and later, in 1908, by Cyrus Borgner, whom you have just re-elected.

There is no living ex-librarian of The Franklin Institute. Alfred Rigling, the present and efficient librarian, has occupied the position since 1887.

Mr. Henry Howson, senior vice-president; Mr. Alfred Rigling, librarian, and the president, are, among the executives of the Institute at the time of my first election to the presidency, the only survivors. The many losses that death has forced upon us during the decade have brought us sorrow.

And a sorrow, heavy indeed, has come upon us this year through the death of James Mapes Dodge—for twenty years a manager, and, at the time of his death, senior vice-president of the Institute. You have just elected his son, Kern Dodge, to the position on the Board made vacant by the death of his distinguished father.

In its financial affairs the Institute has prospered during the decade just elapsed. Ten years ago we were running to an annual deficit of thousands of dollars. We confidently expect that for the year we are just entering the income of the Institute will be equal to its outgo; and we believe that, with the fulfilling of the conditions imposed by the Wahl bequest—which matter is entirely in the hands of its friends—the Institute will have an income justifying it in the occupation of its hoped-for and confidently-anticipated new structure on Logan Square.

The Managers of your Institute would be proud if they could claim that the greatly-improved financial condition of the Institute was due to their efforts. There are generous men connected with the management who have liberally helped the Institute in its time of need, and indeed I could name a few to whose liberality the continuation of the work of the Institute, through what I believe must have been the most trying period of its existence, was mainly due. But the large sums of money that have come to the Institute in the last few years have not come from the personnel of the management. They have come, as legacies, from people who have known the Institute and of its work, and who, seeking to leave some portion of their wealth where it would help to promote the interests of mankind, have selected The Franklin Institute as a fitting instrument to the accomplishment of that end.

The work of the Institute during the decade has been carried on with a success that perhaps has varied, but has certainly never been a negative quantity. The temptation to embark in new fields of activity has been constantly and successfully resisted. The efforts of your Managers have been to do better the work which their predecessors had done well, and to extend the radius of its beneficial influence.

Attached to, and forming a part of, this report are the several reports of your Board's and the Institute's committees, which give in detail an account of the Institute's various activities for the fiscal year ending September 30, 1915.

From a perusal of them the gratifying conclusion is reached that the usefulness of the work of the Institute is well maintained.

Gratifying as is our Finance Committee's report, as compared with its reports of previous recent years, it does not tell the whole story of our present financial condition. Your Board are glad to be able to tell you that since September 30, the date of the expiration of our last fiscal year, the Institute has come into possession of the Shippen Bequest, the income from which, added to the income from other sources, represents an amount equal, or practically equal, to the Institute's current annual expenses, and this despite the fact that such expenses have been greatly increased in recent years. In a word, referring only at the moment to the Institute's financial condition, it may be said that the Institute is operating, for the first time in perhaps fifty years, with practically no annual deficit.

But if the Institute's work is to expand and increase in usefulness, as it assuredly should, and if we are soon to begin the erection of the necessary new and larger building or group of buildings, our present annual income is not sufficient. How to increase the Institute's annual income has been, as you can imagine, a constant concern of your Board and of others equally interested in its welfare. Certainly, one great opportunity affords at the moment, and that opportunity is the meeting of the conditions of the bequest made to the Institute by its late distinguished secretary, Dr. William H. Wahl. The value of Dr. Wahl's estate is some $90,000, which comes to the Institute when an equal sum is subscribed by its friends, and provided such sum is subscribed before the 16th of December next. To the present, only some $25,000 have been subscribed to what we are calling our Wahl Fund. Some $70,000 to $75,000 more are necessary to meet the conditions of this bequest, and your Board cannot too strongly urge the Institute's friends to see that such an amount is subscribed as soon as possible.

With an increase in its productive funds of nearly $200,000 the Institute will be in this financial position—it will have an annual income which will warrant it in going into a new and much larger building, urgently needed for its increasing activities. The Institute owns, and has held in trust for it, what is generally considered the best building site for its purposes in Philadelphia—all paid for and free of liens; and it has something over $200,000 towards the erection of the first building—complete plans and model of which are now being prepared by the architect of the Institute, Mr. Windrim.

Brighter hopes for the future this Institute has probably never had, but their materialization is dependent upon the efforts of the members in its behalf, and in the near future.

Notable among the happenings at the Institute during the past year was the awarding of the first Franklin Medals to Mr. Edison and Professor Onnes, from a fund generously founded by Mr. Samuel Insull, of Chicago.

Your Board believe that the way in which the work of your Science and Arts Committee in encouraging, by various recognitions, invention and scientific discovery is being performed well merits your approval.

You have doubtless observed with pleasure the change in the physical features of the Institute's JOURNAL, which appeared in its new form on January first. Your Committee on Publications should be congratulated on

the success of its efforts to make the JOURNAL, in its mechanical structure, worthy to be the vehicle of the notable writings presented upon its pages. Another feature of the JOURNAL, though not an accomplishment of the past year, is worthy of repeated mention. It is the list of eminent men acting as associate editors. This body of distinguished advisers is a creation of the past few years, and the services of these men are of inestimable value to the JOURNAL, to its readers, and to the promotion of the mechanic arts.

As in previous years, men among the most distinguished in science and technology, in this and other countries, have addressed your meetings and have discovered to you and your friends the latest achievements in the scientific and technical world.

Your library—more cramped for space than ever, by recent valuable accessions—has been rearranged, with the result of increased usefulness.

Your School of Mechanic Arts has flourished and plans are under way for its enlargement.

Your Board hopes that each member of the Institute will read the reports of the committees and so learn more of the condition of the Institute, and of the work done by it, than can be told in the report of the Managers.

The work of these committees and the usefulness of the Institute generally are hampered by two conditions: by lack of space and by location of building. With the one ambition to be of greater service to the citizen and to the State, your Board, and all the workers in our honored institution, urge upon the membership to cut the only fetters which bind it, by raising at once the fund necessary to insure the acquisition of the Wahl Bequest.

Respectfully submitted,

For the Board of Managers,

WALTON CLARK,

President.

PHILADELPHIA, January 19, 1916.

REPORT OF THE COMMITTEE ON LIBRARY

FOR THE FISCAL YEAR ENDING SEPTEMBER 30, 1915.

To the President and Members of The Franklin Institute:

There were expended during the year $928.66 for the purchase of 266 volumes, 2 pamphlets, and 2 diagrams; $1626.25 for subscriptions to magazines and other periodical publications; $824 for binding, rebinding, and repairing of books, and $4821.11 for salaries and general expenses.

There were available for meeting these expenses $7232.76 appropriated by the Board of Managers and $967.26 being the income of the several library funds.

The accessions by gift and from the JOURNAL amounted to 1227 volumes, 1470 pamphlets, and 7 maps.

There was an increase of over 600 titles in the additions of the year when compared with the previous year. This is due chiefly to the continuance of

the practice of applying to engineering firms, industrial establishments, and others for copies of recently-published catalogues and books.

The sorting of the great collection of pamphlets was finished during the past summer. All of a non-technical nature were put aside, and in July 21,100 on medical, historical, and political subjects were transferred to the Free Library. The total number of pamphlets in the library on September 30, 1915, was 29,327. These relate to various branches of technology and science, and the work of preparing them for binding is now under way. Those relating to mechanical subjects will be catalogued at once and will be followed by the other classes.

The following disposition was made of the accumulation of duplicates and non-technical books:

500 volumes of non-technical works, duplicates, and government reports were transferred to the Free Library.

44 volumes of similar material, valued at $32, were transferred to another library to close an old exchange account.

141 volumes were sold for $40 cash.

There are at present only 8 duplicate volumes in stock.

On September 30, 1915, the library contained 67,436 volumes, 29,327 pamphlets, 2288 maps and charts, and 1336 photographs.

The work of preparing the list of current periodicals is nearly finished. Certain checking is now being done to bring it up to date. This list on cards will show the condition of every periodical set in the library. It will give the date when the publication was first issued, the number of volumes, any changes in the title, and the frequency of its appearance. Where the set is not complete, the wants will also be given on the cards. On the completion of this work lists of wants will be issued which can be distributed to second-hand booksellers and magazine dealers. It will then be possible, in the course of time, to complete all the important serials in the library.

The question of binding is still a serious one, but the amount appropriated for this purpose is being expended on such books as are consulted most frequently. A detailed statement of the work of the binder appears elsewhere.

The Committee held meetings each month during the year, excepting in July and August. Many problems connected with the management of the library were given consideration, and books submitted for purchase were carefully examined before being ordered, or were referred to such experts as were willing to aid the Committee in its selections.

The attendance in the library has been as good as heretofore, and a still further increase is noted in the attendance in the evenings.

A detailed statement of the operation of the library is appended hereto.

Respectfully submitted,

CLARENCE A. HALL,

Chairman, Committee on Library.

PHILADELPHIA, January 12, 1916.

APPENDIX.

The following additions were made to the library during the twelve months ending September 30, 1915:

	Bd. Vols.	Unbd. Vols.	Pphs.	Maps	Diagrams
By Gift	626	572	1463	7	
JOURNAL	25	4	7		
Binding	476				
Chemical Periodicals Binding Fund	30				
Purchase:					
Books and Periodicals Account	31	1	1		
Income: Lea Fund	31	3	1		
Moore Fund	134	19			2
Morris Fund	29				
Potts Fund	12	6			
	1394	605	1472	7	2

Total additions for the year 3480

Gifts of books, pamphlets, periodical publications, and maps and charts in large quantities or of special value were received from:

Messrs. N. W. Akimoff, W. D. Anderson, H. M. B. Bary, Miss Booth, The Cassela Color Company, Mr. George S. Cullen, The Engineers' Club, Messrs. Spencer Fullerton, Richard Gilpin, Clarence A. Hall, Prof. L. M. Haupt, Messrs. Harris & Richards, Messrs. Helme & McIlhenny, Drs. Carl Hering, Charles F. Himes, Harry F. Keller, Henry Leffmann, Mr. F. N. Morton, Miss Peuckert, The Philadelphia Book Company, Messrs. L. E. Picolet, C. W. Pike, Mrs. Max Riebenack.

The Committee is again indebted to Mr. Joseph A. Arnold, Editor and Chief of the Division of Publications, U. S. Department of Agriculture, for copies of current publications of the Department.

BINDING.

The work done in the bindery was as follows:

	Bound	Repaired	Rebound
Recent volumes of periodicals	476		
Recent volumes of periodicals charged to Chemical Periodicals Binding Fund	30		
Old volumes		1	3
Books purchased with the income of:			
Moore Fund	1		1
Morris Fund		1	

REPORT OF THE COMMITTEE ON MUSEUMS

FOR THE FISCAL YEAR ENDING SEPTEMBER 30, 1915.

To the President and Members of The Franklin Institute:

The following models and apparatus have been added to the Institute's collections:

15-Kilowatt Multiple Magnet K-type Edison Dynamo. Gift of the Wm. Cramp & Sons Ship and Engine Building Company.

Rotary Steam Engine. Gift of the Herrick Engine Company.

Original apparatus used by Dr. Edwin F. Northrup in his experiments and investigations on vortex motions in liquids. Gift of Dr. Northrup.

Early form of Berliner Gramophone. Gift of Mr. Henry Howson.

During the year the front south basement room was cemented and the large models were assembled and set up. Shelving was placed on the south wall for small models and apparatus.

The various exhibits in the Committee's care have received proper attention and are all in good order.

Respectfully submitted,

ALEX. E. OUTERBRIDGE, JR.,
Chairman.

PHILADELPHIA, January 12, 1916.

REPORT OF THE COMMITTEE ON MEETINGS

FOR THE FISCAL YEAR ENDING SEPTEMBER 30, 1915.

To the President and Members of The Franklin Institute:

Eight stated meetings were held during the year with an attendance of 1515 members and visitors.

At the May meeting the first presentation of the Franklin Medal was made to his Excellency, Chevalier van Rappard, on behalf of the Royal Netherlands Government, for Prof. Heike Kamerlingh Onnes, of the University of Leiden, and to Thomas Alva Edison, Esq., of Orange, N. J. A bronze replica of the artist's model of the Franklin Medal was presented to the Institute by the sculptor of the medal, Dr. R. Tait McKenzie, and another replica was presented by the Institute to Samuel Insull, Esq., of Chicago, Ill., founder of the medal fund. After the meeting a reception was tendered to his Excellency, Chevalier van Rappard, and Messrs. Edison and Insull in the rooms of the Historical Society of Pennsylvania.

The following papers were presented during the year:

October 21, 1914.

"The Earth a Great Magnet." Dr. L. A. Bauer, Director, Department of Terrestrial Magnetism, Carnegie Institution of Washington.

November 18, 1914.

"The Photography and Analysis of Sound Waves." Dr. Dayton C. Miller, Professor Physics, Case School of Applied Science, Cleveland, Ohio.

December 16, 1914.

"An American Engineer in China." Dr. William B. Parsons, Consulting Engineer, New York City.

January 20, 1915.

"Conditions Affecting the Success of Main Line Electrification." Mr. William S. Murray, Consulting Engineer, New York, New Haven and Hartford Railroad, New Haven, Conn.

February 17, 1915.

"Sanitation and Accident Prevention in Industry." Dr. Francis D. Patterson, Director, Department of Sanitation and Accident Prevention, Harrison Bros. & Co., Inc., J. G. Brill Company, and Electric Storage Battery Company, Philadelphia.

March 17, 1915.

"High Temperature Investigations." Dr. Edwin F. Northrup, Palmer Physical Laboratory, Princeton, N. J.

April 21, 1915.

"Mechanical Stoking of Locomotives." Mr. W. S. Bartholomew, President, Locomotive Stoker Company, Schenectady, N. Y.

May 19, 1915.

"Electricity and Modern Industrial Growth." Samuel Insull, Esq.

A special meeting conducted jointly by the Institute and the Philadelphia Section of the Illuminating Engineering Society was held on Friday evening, March 19, 1915. Two papers were presented, one by Dr. Herbert E. Ives and E. F. Kingsbury, entitled "Method of Securing Uniformity of Readings on the Flicker Photometer with Different Observers," and another by Professor John Hammond Smith, of the University of Pittsburgh, on "Photo-sculpturing."

Dr. W. F. M. Goss, who was originally scheduled to address the meeting of April 21, was unable to be present, and Dr. Edwin F. Northrup, who had been announced to present a paper before the sections, was invited to address the meeting.

Nearly all the above papers have since appeared in the JOURNAL.

Respectfully submitted,

JAMES S. ROGERS,
Chairman.

PHILADELPHIA, January 12, 1916.

REPORT OF THE COMMITTEE ON INSTRUCTION

FOR THE FISCAL YEAR ENDING SEPTEMBER 30, 1915.

To the Board of Managers:

The courses offered in the ninety-first year of the Institute's School of Mechanic Arts, commencing in September, 1914, were substantially the same as those given in the preceding year, and the division of the instructional work into the four Departments of Drawing, Mathematics, Mechanics, and Naval Architecture was maintained.

The School opened on September 14, 1914, and during the year two hundred and sixty-seven students enrolled. This represented a decrease of fifty-three from the preceding year, and, judging from the number of requests for deferred payment of fee, was probably due to the prevailing industrial conditions. The largest classes formed during the year were those in Drawing and Mathematics.

The faculty for the year was as follows:

Professor William H. Thorne, Director of the School, and in charge of the Department of Drawing.

Professor William E. Bullock, Assistant Director, and in charge of the Department of Mechanics.

Professor Simeon van T. Jester, in charge of the Department of Mathematics.

Professor H. C. Towle, in charge of the Department of Naval Architecture.

Professor Thorne was assisted in his Department by Professor Clement Remington, in charge of Architectural and Freehand Drawing, and by Messrs. F. H. Lobb, I. P. Pedrick, C. Rommel, and W. W. Twining, instructing in Mechanical Drawing.

Mr. H. S. Detwiler assisted in the Department of Mathematics, and Messrs. E. Bark and M. M. Mark in Mechanics.

The attendance in the School throughout the year was well above the average, and exceptionally good work was done in all departments.

During the year students of the School, accompanied by instructors, visited the following places of interest:

Millbourne Mills, Sixty-third and Market Streets, Philadelphia, Pa.

Otto Gas Engine Works, Thirty-third and Walnut Streets, Philadelphia, Pa.

Curtis Publishing Company, Independence Square, Philadelphia, Pa.

Beach Power House, Philadelphia Rapid Transit Company, Beach and Laurel Streets, Philadelphia, Pa.

Link Belt Company, Hunting Park Avenue, Philadelphia, Pa.

Engineering Building, University of Pennsylvania, Thirty-third and Walnut Streets, Philadelphia, Pa.

Bureau of Water, Queen Lane Pumping Station, Fairmount Park, Philadelphia, Pa.

In every case the attendance was good and much interest was shown by those present. Our thanks are due to the managements represented for their courtesy.

The graduating exercises were held in the Hall of the Institute on the

evening of April 16, 1915. Dr. Walton Clark, President of the Institute, occupied the chair, and the graduating address was delivered by Dr. George A. Hoadley, Professor Emeritus of Physics, Swarthmore College, Swarthmore, Pa. The Alumni Association was represented by Mr. John F. Abbott. The annual report of the work of the School was presented by Professor Thorne. Sixty-one students were graduated: thirty-one in Mechanical Drawing, three in Architectural Drawing, two in Freehand Drawing, eighteen in Mathematics, four in Mechanics, and three in Naval Architecture. Three students in the Department of Drawing, one in the Department of Mathematics, and one in the Department of Mechanics were the recipients of the Edmonds Scholarships. Twelve students in the Department of Drawing were the recipients of scholarships from the B. H. Bartol Fund entitling them to free instruction. Six students were awarded free scholarships from the Isaac B. Thorn Fund. The student in the Department of Drawing having the best set of drawings for the year was awarded a prize donated by Mr. W. D. Baldwin, President of the Otis Elevator Company. The student of greatest merit in the Department of Mathematics was awarded a prize donated by Mr. J. B. McCall, President of The Philadelphia Electric Company. Two Prizes in the Department of Mechanics were awarded to students of greatest merit, one by Mr. Wilfred Lewis, President of the Tabor Manufacturing Company, and the other by Mr. S. M. Vauclain, Vice-president of The Baldwin Locomotive Works. A set of drawing instruments, offered by the New York Shipbuilding Company, was awarded to the student of greatest merit in the Department of Naval Architecture. Six graduates received awards provided by the Alumni Association of The Franklin Institute, and ten graduates making a perfect attendance record were awarded free membership for one year in the Association. In the Winter Term thirty-five students were awarded certificates of Honorable Mention; forty-seven students received similar certificates in the Spring Term.

The registration figures for the year, as well as for the previous year for comparison, follow:

	1913–14		1914–15	
	Winter Term Sept.–Dec.	Spring Term Jan.–Apr.	Winter Term Sept.–Dec.	Spring Term Jan.–Apr.
Drawing	188	148	154	125
Mathematics	71	57	70	51
Mechanics	30	28	30	22
Naval Architecture	17	15	4	4
	306	248	258	202

A lecture, entitled "West Indies and the Spanish Main," was delivered in the Hall of the Institute, by Mr. Frederick Monsen, F. R. G. S., on January 15, 1915, under the auspices of the Alumni Association, to which all the students were invited.

The graduates were invited to the annual smoker and luncheon of the Alumni Association, held on the evening of Saturday, April 10, 1915. At the luncheon 124 covers were laid, and speeches were made by Mr. L. E. Levy, Professor Thorne, and Mr. Abbott.

During the summer the School Calendar was published and all preparations made for the ninety-second session. Valuable prizes were again donated

by Mr. S. M. Vauclain, Mr. W. D. Baldwin, Mr. J. B. McCall, Mr. Wilfred Lewis, the New York Shipbuilding Company, and the Alumni Association.

A schedule of visits to engineering establishments was arranged.

Respectfully submitted,

LAWRENCE T. PAUL,
Chairman.

PHILADELPHIA, January 12, 1916.

REPORT OF THE COMMITTEE ON ELECTIONS AND RESIGNATIONS OF MEMBERS

FOR THE FISCAL YEAR ENDING SEPTEMBER 30, 1915.

To the Board of Managers:

During the fiscal year ending September 30, 1915, there were fifty-five members enrolled; resignations were received and accepted from fifty-nine members; and deaths were recorded of twenty-eight members.

The figures for the several classes of membership and for the two preceding years follow:

	1912–13	1913–14	1914–15
ELECTIONS:			
Resident Members	101	47	25
Non-Resident Members	186	57	24
Associate Members	1	7	2
Honorary Members	0	0	0
Life Members	3	0	4
	291	111	55
RESIGNATIONS:			
Resident Members	16	17	30
Non-Resident Members	13	12	25
Associate Members	2	2	3
Second Class Stock			1
	31	31	59
DEATHS:			
Resident Members	8	6	9
Non-Resident Members	4	4	8
Life Members	6	14	9
Honorary Members	1	2	0
Associate Members	0	0	0
Second Class Stock			2
	19	26	28
SUMMARY:			
Total Elections	291	111	55
Total Resignations	31	31	59
Total Deaths	19	26	28

Net decrease in membership 32

Respectfully submitted,

W. C. L. EGLIN,
Chairman.

PHILADELPHIA, January 12, 1916.

REPORT OF THE COMMITTEE ON STOCKS AND FINANCE FOR THE YEAR 1915.

FINANCIAL STATEMENT, OCTOBER 1, 1914, TO SEPTEMBER 30, 1915.

PROPERTY AND FUNDS.

Building and land, 13–17 South Seventh Street		$60,000.00	
Library		100,000.00	
			$160,000.00
	Principal	Income	Unexpended
Funds held by Board of Trustees	$280,859.14	$514.02	
Funds held by Board of Managers	17,122.45	34.21	(overdrawn)
Franklin Institute Building Fund	371,666.30		
Elliott Cresson Medal Fund	3,000.00	105.70	
Franklin Fund and Building Committee	4,483.36		
Total funds	$683,494.75	$585.51	684,080.26
Grand total			$844,080.26

LIABILITIES.

Certificates of Stock	$29,870.00
Mortgage on Institute Building (held by Trustees as investment for funds)	30,000.00
Bills payable	27,250.00
Accounts payable	4,543.97
Unearned income	1,117.75
Edmonds Scholarship donation	50.00
Grand total	$92,831.72

INCOME AND EXPENSES APPLICABLE TO YEAR ENDING SEPTEMBER 30.

Income.

Dues			$10,598.53
Initiation fees			110.00
General Endowment Fund			10,008.62
James H. Cresson Memorial Fund			2,267.92
John Scott Medal Fund			900.00
Estate of John Turner			124.97
Estate of Robert Wright			1,885.82
Instruction: Drawing		$1,370.00	
Mathematics		600.00	
Mechanics		260.00	
Naval Architecture		50.00	
			2,280.00
Publications: Subscriptions and Sales		$1,956.36	
Advertising		2,411.47	
			4,367.83
Total			$32,543.69

Expenses.

Building:	Wages	$1,211.75	
	Repairs and maintenance	649.86	
	Taxes, water rent and insurance	548.19	
	Heat, light, and power	662.46	
	Miscellaneous supplies and expense	264.50	
			$3,336.76
Elections and resignations			171.48
Instruction:	Drawing	$1,096.00	
	Mathematics	333.00	
	Mechanics	312.50	
	Naval Architecture	172.00	
	Miscellaneous Expense	1,158.27	
	Popular Lectures	69.75	
			3,141.52
Library:	Salaries	$4,612.02	
	Books and periodicals	1,626.25	
	Binding	785.40	
	Miscellaneous expense	209.09	
			7,232.76
Meetings			772.56
Office and General:	Salaries	$8,384.09	
	Office expense	770.94	
	General expense	1,405.00	
			10,560.03
Publications:	Printing	$5,729.95	
	Reprints	685.44	
	Illustrating	695.38	
	Miscellaneous expense	658.30	
	Year-Book	500.00	
			8,269.07
Science and Arts			1,584.76
Sections			1,076.15
Basement renovation			380.46
Interest and discount			1,876.76
Membership badges			20.05
Miscellaneous income and expense			191.19
Total			$38,613.55
Deficit			$6,069.86

During the fiscal year the only important change in any of the Institute's funds has been an increase, through income, of The Franklin Institute Building Fund of $7741.99. There has been an increase in bills payable of $7000.

Respectfully submitted,

WALTON FORSTALL,
Chairman.

PHILADELPHIA, January 12, 1916.

REPORT OF THE COMMITTEE ON PUBLICATIONS

FOR THE FISCAL YEAR ENDING SEPTEMBER 30, 1915.

To the Board of Managers:

In the closing month of the past year the Institute completed the publication of the 180th volume of its Journal of Science and the Mechanic Arts, and the 90th year's record of its Transactions. A review of these publications and of their significance as milestones marking the advances of Science and the Arts during these nine decades may well be left for the time ten years hence, when the JOURNAL OF THE FRANKLIN INSTITUTE will have completed a full century's record of progress in the field of its activity, but at the present juncture it may be no less proper to point to the issues of the past year as evidences of the increasing scope of that activity. More than ever before the JOURNAL OF THE INSTITUTE has become a record not only of the advances made in the field of the applied sciences, but also of researches which open the way to further progress. The field widens from day to day, and the volumes of our record thicken from year to year.

In keeping up this record your Committee has endeavored to coöperate to the fullest possible extent with the Editor of the JOURNAL and with the Board of Associate Editors, to whose collaboration in this respect the Institute is largely indebted. A welcome addition to this Board has recently been afforded us through the adhesion of Dr. A. S. Eve, Professor of Physics at McGill University in Montreal. Your Committee has also the satisfaction of reporting that the Notes of Research Work from the U. S. Bureau of Standards, which have been published in the JOURNAL throughout the past year, have latterly been supplemented by those of the Nela Research Laboratory of the National Electric Light Association, and also by similar communications from the Research Laboratory of the General Electric Company and from that of the Eastman Kodak Company.

The Year-Book of the Institute, revised to the end of our last fiscal year and amplified by the reports of the President of the Institute and of its various standing Committees, was published in due course last October. The edition was materially increased to permit of its being distributed among scientific institutions and technical societies at home and abroad as a means of increased publicity for the Institute in general and also in furtherance of the Membership Campaign latterly undertaken and now in progress.

The expense of publishing the JOURNAL and the Year-Book during the past fiscal year, including reprints furnished to authors of articles printed in the JOURNAL, was $8269.07. The income from subscriptions and sales of the JOURNAL and of extra numbers of reprints was $1956.36, and from the Advertising Account $2411.47, leaving a balance of $3901.24 to be accounted as the cost of the JOURNAL furnished to the individual members of the Institute.

Respectfully submitted,

LOUIS E. LEVY,
Chairman.

PHILADELPHIA, January 12, 1916.

REPORT OF THE COMMITTEE ON SECTIONAL ARRANGEMENTS

FOR THE FISCAL YEAR ENDING SEPTEMBER 30, 1915.

To the Board of Managers of The Franklin Institute:

During the year ending September 30, 1915, twenty lectures were delivered, as follows:

SECTION OF PHYSICS AND CHEMISTRY—*Five Meetings.*

October 1, 1914.

"The Ultra-violet Rays and Their Application for the Sterilization of Water." Max von Recklinghausen, Ph.D., The R. U. V. Company, Inc., New York City, N. Y.

November 5, 1914.

"Artistic Painting and the Secrets of the Old Masters." Maximilian Toch, Ph.D., Director of Research Laboratory, Toch Brothers, New York City, N. Y.

December 3, 1914.

"Modern Views on the Constitution of the Atom." A. S. Eve, D.Sc., Professor of Physics, McGill University, Montreal, Canada.

January 28, 1915.

"The Production of Light by Animals." Ulric Dahlgren, Ph.D., Professor of Biology, Princeton University, Princeton, N. J.

February 4, 1915.

"Moisture in Agricultural Products." C. L. Alsberg, Ph.D., Chief, Bureau of Chemistry, U. S. Department of Agriculture, Washington, D. C.

MECHANICAL AND ENGINEERING SECTION—*Five Meetings.*

November 12, 1914.

"Biochemical and Engineering Aspects of Sanitary Water Supplies." George W. Fuller, C.E., Consulting Hydraulic and Sanitary Engineer, New York City, N. Y.

December 10, 1914.

"The Modern Submarine in Naval Warfare." R. H. M. Robinson, Managing Director, Lake Torpedo Boat Company, Bridgeport, Conn.

January 7, 1915.

"The Organization, Character of Personnel, Scope of Work, and Methods of Operation and Control of a Large Municipal Highway Department." William H. Connell, Chief, Bureau of Highways and Street Cleaning, Philadelphia, Pa.

March 4, 1915.

"Hydraulic Works of the Panama Canal." Carleton E. Davis, Chief, Bureau of Water, Philadelphia, Pa.

April 8, 1915.

"Rapid Transit Problems in Philadelphia." H. H. Quimby, C.E., Chief Engineer, Department of City Transit, Philadelphia, Pa.

ELECTRICAL SECTION—*Three Meetings.*

February 11, 1915.

"Recent Researches in Electricity at the Bureau of Standards." E. B. Rosa, Ph.D., Chief Physicist, Bureau of Standards, Washington D. C. (Joint meeting with Philadelphia Section, American Institute of Electrical Engineers.)

April 1, 1915.

"Modern Theories of Magnetism." George F. Stradling, Ph.D., Head of Science Department, Northeast High School, Philadelphia, Pa. (Joint meeting with Philadelphia Section, American Institute of Electrical Engineers.)

April 15, 1915.

"Control and Protection of Electric Systems." Charles P. Steinmetz, M.A, Ph.D., Consulting Engineer, General Electric Company, Schenectady, N. Y. (Joint meeting with Philadelphia Section, American Institute of Electrical Engineers.)

SECTION OF PHOTOGRAPHY AND MICROSCOPY—*Four Meetings.*

October 15, 1914.

"Recent Advances in Photographic Chemistry." Henry Leffmann, M.D., Ph.D., Philadelphia, Pa. (Joint meeting with Photographic Society of Philadelphia.)

October 28, 1914.

"Physics of the Photographic Process." C. E. K. Mees, D.Sc., Director of Research Laboratory, Eastman Kodak Company, Rochester, N. Y. (Joint meeting with Photographic Society of Philadelphia.)

February 25, 1915.

"Recent Progress in the Making of Photographs in Color." Henry Hess, M.E., Philadelphia, Pa. (Joint meeting with Photographic Society of Philadelphia.)

March 25, 1915.

"Recent Advances in the Technographic Arts." Louis Edward Levy, Photo-chemist, President, Graphic Arts Company, Philadelphia, Pa.

MINING AND METALLURGICAL SECTION—*Two Meetings.*

January 14, 1915.

"Modern Steels and Their Heat Treatment." R. R. Abbott, B.S., M.E., Metallurgical Engineer, The Peerless Motor Car Company, Cleveland, Ohio. (Joint meeting with American Society of Mechanical Engineers.)

October 8, 1914.

"Recent Developments in Cast Iron Manufacture." J. E. Johnson, Jr., Consulting Engineer and Metallurgist, New York City, N. Y. (Joint meeting with American Society of Mechanical Engineers.)

One special meeting of the Sections and the Philadelphia Chapter of the American Institute of Architects was held on Friday evening, October 30, 1914. A paper was presented by Dr. Wallace C. Sabine, Dean of the Graduate School of Applied Science, Harvard University, Cambridge, Mass., on "Architectural Acoustics."

Nine joint meetings were held, one with the Philadelphia Chapter, American Institute of Architects; two with the American Society of Mechanical Engineers; three with the Philadelphia Section, American Institute of Electrical Engineers, and three with the Photographic Society of Philadelphia.

Lantern slides, special apparatus, and exhibits were used to illustrate the lectures. The greater number of papers were referred to the Committee on Publications for publication in the JOURNAL.

The attendance at the meetings still continues to increase; on three occasions the hall was taxed beyond its capacity.

Respectfully submitted,

CHARLES DAY,
Chairman.

PHILADELPHIA, January 12, 1916.

REPORT OF THE COMMITTEE ON ENDOWMENT

FOR THE FISCAL YEAR ENDING SEPTEMBER 30, 1915.

To the Board of Managers:

Your Committee begs leave to make the following report:

During the past year an effort was made to secure additional subscriptions to meet the terms of the bequest of Dr. Wahl to The Franklin Institute, in which the Institute was named residuary legatee at the death of Mrs. Wahl on condition that an amount equal to that of the estate be subscribed within three years after Mrs. Wahl's death. The time will expire December 16, 1916. The value of the estate is approximately Eighty-five Thousand Dollars ($85,000). Subscriptions have been received amounting to Twenty-five Thousand, One Hundred and Fourteen Dollars ($25,114). During the coming year we must obtain subscriptions amounting to, at least, Sixty-five Thousand Dollars ($65,000).

May we ask that every member make a prompt and liberal subscription to this fund. We do not wish to limit the subscriptions to Members of the Institute, and will be glad to receive subscriptions from all who are interested in the promotion of the Mechanic Arts.

The Wahl Bequest to The Franklin Institute and the like sum subscribed will enable the Franklin Fund and Building Committee to at once take steps

to erect a suitable building on the site owned by the Institute at the southeast corner of Nineteenth and Race Streets.

During the past year the estate of Elizabeth Shippen has been settled. The Franklin Institute was one of the six residuary legatees. The Institute's proportion of the residuary estate is as follows:

Principal	$158,068.89
Accumulated interest	17,875.87

The principal, as soon as it is received, will be transferred to the Board of Trustees of the Institute for investment.

Respectfully submitted,

HENRY HOWSON,
Chairman.

PHILADELPHIA, January 12, 1916.

REPORT OF THE COMMITTEE ON SCIENCE AND THE ARTS

FOR THE FISCAL YEAR ENDING SEPTEMBER 30, 1915.

To the President and Members of The Franklin Institute:

Your Committee on Science and the Arts has the honor to submit the following account of its activities for the year ending September 30, 1915.

At the April meeting Mr. William Chattin Wetherill was elected to serve on the Committee, to fill the unexpired term of Mr. Tinius Olsen, who removed from the city.

The resignation of Mr. William E. Bullock, Science and Arts Assistant, was announced at the June meeting.

Mr. T. R. Parrish was appointed, September 1, to fill the vacancy left by Mr. Bullock.

At the September meeting the following resolution was adopted on the occasion of the death of Richard Gilpin, member of the Committee:

> "The Committee on Science and the Arts of The Franklin Institute, sensible of the loss its membership has sustained through the untimely death of Richard Gilpin, on June 21, unanimously resolves that there be recorded in its minutes this present memorial of the faithful service rendered by Richard Gilpin as member of this body during the past eleven years, in recognition of his efficient collaboration as a technologist, and in appreciation of the sterling qualities of his genial personality. The Committee further resolves that this minute be published in the JOURNAL OF THE INSTITUTE, and that an engrossed copy thereof be transmitted to the family of the deceased."

The Committee investigated and disposed of thirty cases during the year.

The average attendance at the stated meetings was 20.3, or 33 per cent. above the quorum necessary for all action on reports. At no meetings was the attendance less than seventeen.

The Sub-committee on New Subjects and Preliminary Examination held one meeting before each stated meeting of the Committee. During the year it

considered seventy-one subjects and recommended nineteen for examination. Sixteen applications for investigation resulted from such recommendations.

In accordance with the recommendation of the Sub-committee on New Subjects and Preliminary Examination, a blank card, on which might be suggested new subjects for examination, was sent to each member of the Committee with the notice of each stated meeting. Fifteen subjects were suggested by means of these cards.

Appended to this report is a detailed statement of the operation of the Committee during the year. The number of awards recommended by standing sub-committees and sub-committees of investigation is as follows:

SUB-COMMITTEE ON THE FRANKLIN MEDAL.

Number of awards 2

SUB-COMMITTEE ON LITERATURE.

Number of Potts Medals recommended 1
Number of Longstreth Medals recommended 4

SUB-COMMITTEES ON APPLICATIONS FOR INVESTIGATION.

Number of awards recommended 14

Your Committee has continued the practice of having an informal dinner prior to each meeting. The average attendance at these dinners was twelve.

During the year many of the inventors and investigators whose work was favorably recommended by your Committee were present at the stated meetings of the Institute and received in person the medals awarded them. The Chairman made brief statements relative to the work of each, and introduced them to the President, who made the presentations on behalf of the Institute.

Efforts have been made to extend the knowledge of the work of your Committee. Cards were printed giving a list of the awards at the Institute's disposal, or made on its recommendation, together with the conditions under which the awards are made, and sent to engineering, scientific, and educational bodies. The work of the Committee was also brought to the attention of the officers of the Panama-Pacific Exposition, in San Francisco, Cal.

The Franklin Medal Fund, founded by Mr. Samuel Insull, of Chicago, Ill., and the award of the medals to Thomas Alva Edison, of Orange, N. J., and Prof. Heike Kamerlingh Onnes, of Leiden, Holland, have done much to further bring the activities of the Institute to the attention of the lay as well as the scientific world.

The work of the past year was of exceptional interest, and the investigations made by the sub-committees, as well as the other work of the Committee, was carefully and thoroughly done.

Respectfully submitted,

G. H. CLAMER,
Chairman.

PHILADELPHIA, January 12, 1916.

APPENDIX.

STATEMENT OF THE COMMITTEE'S OPERATION FOR THE YEAR ENDED SEPTEMBER 30, 1915.

CASES.

Cases pending, October 1, 1914		18
Applications during the year	16	
Special reports	7	
	—	23
		—
		41
Disposed of during the year		30
		—
Leaving pending		11

DISPOSITION OF CASES.

Franklin Medal Awards	2
Elliott Cresson Awards	1
Howard N. Potts Awards	1
Edward Longstreth Awards	7
John Scott Legacy Recommendations	8
Certificates of Merit	2
	—
	21

AWARDS MADE DURING THE YEAR.

THE FRANKLIN MEDAL.

Thomas Alva Edison, of Orange, N. J., in recognition of the value of numerous basic inventions and discoveries forming the foundation of world-wide industries, signally contributing to the well-being, comfort, and pleasure of the human race.

Prof. Heike Kamerlingh Onnes, of Leiden, Holland, in recognition of his long-continued and indefatigable labors in low-temperature research which have enriched physical science, not only with a great number of new methods and ingenious devices but also with achievements and discoveries of the first magnitude.

THE ELLIOTT CRESSON MEDAL.

Michael J. Owens, of Toledo, Ohio, for his Automatic Bottle Machine.

THE HOWARD N. POTTS MEDAL.

William J. Humphreys, C.E., Ph.D., of Washington, D. C., for his paper on "The Thunderstorm and its Phenomena," in the November and December, 1914, issues of the JOURNAL.

THE JOHN SCOTT LEGACY MEDAL AND PREMIUM.

Cav. Ing. Alberto Cerasoli, of Rome, Italy, for the Humphrey Pump.

Harold N. Anderson, of Cleveland, Ohio, for his Gear Rolling Machines.

Hyman Eli Goldberg, of Chicago, Ill., for the Wahl Calculating Attachment for Typewriters.

H. W. Hardinge, of New York, N. Y., for his Conical Pebble Mill.

Herbert Alfred Humphrey, of London, England, for the Humphrey Pump.

A. Atwater Kent, of Rosemont, Pa., for his Unisparker.

Elmer A. Sperry, of New York, N. Y., for his Gyro-Compass.

John C. Wahl, of Chicago, Ill., for the Wahl Calculating Attachment for Typewriters.

THE EDWARD LONGSTRETH MEDAL.

Edward J. Dobbins, of London, England, for his Daylight Rods.

Herbert E. Ives, Ph.D., of Philadelphia, Pa., for his paper on "Artificial Daylight," in the May, 1914, issue of the JOURNAL.

Max von Recklinghausen, Ph.D., of New York City, N. Y., for his paper on "The Ultra-violet Rays and Their Application for the Sterilization of Water," in the December, 1914, issue of the JOURNAL.

C. C. Tutwiler, A.B., M.S., of Philadelphia, Pa., for his paper on "The Recovery of Gas Works By-products," in the October, 1914, issue of the JOURNAL.

Wahl Adding Machine Company, of Chicago, Ill., for the Development of the Means for Manufacturing the Wahl Calculating Attachment for Typewriters.

George A. Wheeler, deceased, of Brooklyn, N. Y., for his Escalator.

C. D. Young, of Altoona, Pa., for his paper on "Locomotive Superheaters and Their Performance," in the July and August, 1914, issues of the JOURNAL.

THE CERTIFICATE OF MERIT.

W. A. Blonck, of Chicago, Ill., for his Blonck Boiler Efficiency Meter.

George P. Vanier, of Steelton, Pa., for his Potash Bulb.

JOHN SCOTT MEDAL RECOMMENDATIONS.

(Awards pending, September 30, 1915.)

Hans Hanson, of Hartford, Conn., for his invention embodied in John Underwood and Company's Combined Typewriting and Calculating Machine.

Frederick A. Hart, of New York City, N. Y., for his inventions embodied in John Underwood and Company's Combined Typewriting and Calculating Machine.

Clement F. Street, of New York City, N. Y., for his Street Locomotive Stoker.

THE EDWARD LONGSTRETH MEDAL.

(Award pending, September 30, 1915.)

John Underwood and Company, of Hartford, Conn., for the development of methods and means for the manufacture of the Combined Typewriting and Calculating Machine.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, January 5, 1916.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 5, 1916.

MR. L. E. LEVY, *Chairman pro tem.*

The following report was presented for first reading:

No. 2634.—Cement-Gun.

Mr. John V. N. Dorr, of New York City, N. Y., described his Hydrometallurgical Apparatus.

R. B. OWENS,
Secretary.

SECTIONS.

Section of Physics and Chemistry.—A stated meeting of the Section was held in the Hall of the Institute on Thursday, January 6, 1916, at 8 o'clock P.M., with Dr. Walton Clark in the chair. The minutes of the previous meeting were read and approved.

Fred H. Wagner, M.E., Chief Engineer of the Bartlett Hayward Company, Baltimore, Md., delivered an illustrated lecture on "Coal Gas Residuals." A description was given of the various methods employed in the by-product coke industry for the recovery, separation, and purification of ammonia and its salts, tar, benzol, toluol, naphthalene, phenol, cresol, and cyanogen. The procedures for the manufacture of dyes, synthetic drugs, chemical reagents, and explosives from the raw material were outlined. A vote of thanks was extended to the lecturer and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, January 12, 1916.)

RESIDENT.

MR. H. W. BIDDLE, stock broker, 424 Chestnut Street, Philadelphia, Pa.

MR. WILSON CATHERWOOD, merchant, 1708 Walnut Street, Philadelphia, Pa.

MR. J. H. CUMMINGS, President, John B. Stetson Company, Philadelphia, Pa.

MR. FRANKLIN C. GURLEY, chemist, Benzol Products Company, Marcus Hook, Pa.

MR. ROBERT B. LEWIS, Mechanical Engineer, 4611 Wayne Avenue, Philadelphia, Pa.

MR. THORSTEN Y. OLSEN, Vice-President and Treasurer, Tinius Olsen Testing Machine Company, 500 North Twelfth Street, Philadelphia, Pa.

NON-RESIDENT.

MR. R. H. BALLARD, Secretary and Assistant Engineer, Southern California Edison Company, Edison Building, Los Angeles, Cal.

MR. T. E. CLARKE, Assistant to President, The Delaware, Lackawanna and Western Railroad Company, Scranton, Pa.

REV. JOSEPH A. CORCORAN, M.D., S.J., Professor of Chemistry, Loyola College, Montreal, Quebec.

MR. D. F. CRAWFORD, General Superintendent of Motive Power, Pennsylvania Lines West of Pittsburgh, Pennsylvania Station, Pittsburgh, Pa.

MR. OLIVER C. CROMWELL, Mechanical Engineer, Baltimore and Ohio Railroad Company, Mt. Clare, Baltimore, Md.

MR. GEORGE H. EMERSON, General Manager, Great Northern Railway Company, St. Paul, Minn.

MR. W. H. FINLEY, Chief Engineer, Chicago and Northwestern Railway Company, Chicago, Ill.

MR. W. W. FREEMAN, President, The Union Gas and Electric Company, Fourth and Plum Streets, Cincinnati, Ohio.

MR. JOHN F. GILCHRIST, Vice-President, Commonwealth Edison Company, Edison Building, Chicago, Ill.

MR. TABER HAMILTON, Master Mechanic, Cumberland Valley Railroad Company, Chambersburg, Pa.

MR. RICHARD P. HARVEY, Resident Engineer, Blau Steel Construction Company, 225–227 Monadnock Block, San Francisco, Cal.

MR. B. T. JELLISON, Purchasing Agent, Chesapeake and Ohio Railway Company, Richmond, Va.

MR. P. JUNKERSFELD, Assistant to Vice-President, Commonwealth Edison Company, Edison Building, Chicago, Ill.

MR. R. B. KENDIG, Chief Mechanical Engineer, The New York Central Railroad Company, Grand Central Terminal, New York City, N. Y.

MR. M. C. KENNEDY, President, Cumberland Valley Railroad Company, Chambersburg, Pa.

MR. EDWIN KUTTROFF, President, Verona Chemical Company, North Newark, N. J.

MR. WILL G. LENKER, Civil Engineer, 405 Chestnut Street, Sunbury, Pa.

PROF. H. M. MCCORMACK, Department of Chemical Engineering, Armour Institute of Technology, Chicago, Ill.

MR. A. C. NEEDLES, General Manager, Norfolk and Western Railway Company, Roanoke, Va.

MR. R. S. ORR, General Manager, Duquesne Light Company, Pittsburgh, Pa.

MR. JOHN PURCELL, Assistant to Vice-President, Atchison, Topeka and Santa Fé Railway System, 80 East Jackson Boulevard, Chicago, Ill.

MR. R. QUAYLE, General Superintendent of Motive Power and C. D., Chicago and Northwestern Railway Company, Station "E," Chicago, Ill.

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A Practicable Example of Air-cooling. ANON. (*The Autocar,* vol. xxxv, No. 1053, December 25, 1915.)—The one and only representative of the air-cooled engine in the motor world sold as an every-day product is the Franklin. The car is not known except by name in Europe, but it has been for many years a standard product in the United States, and a very high standard of performance has been achieved. Its last record has just been completed under the official observation of the Automobile Club of America, and on this occasion the consumption of lubricating oil was carefully tested and was found to work out at 1046 miles per gallon. While this is far from being a record in low consumption, it is more than sufficient to show that the engine is by no means extravagant in the consumption of lubricating oil. A complaint frequently brought against the air-cooled engine is that of enormous oil consumption, extremists maintaining that, although water is dispensed with, so much lubricating oil is used that the engine might be called an oil-cooled rather than a water-cooled motor. The Franklin car upon which the particular tests were made is five-seated with closed body.

Only the bare results are at present available, but the engine is by no means a diminutive one, having six cylinders 90×102 mm. The car is very light, special attention having been given to the reduction of weight. The cylinder flanges are vertical, and a hood with open ends is placed over the engine. Vanes in the fly-wheel pull a current of air through the hood which conveys the heat from the flanges backward out of the bonnet. As the sole representative of the air-cooled motor car it is a most interesting machine, and its latest performance certainly disposes of the reproach as to excessive oil consumption.

CURRENT TOPICS.

Benzol Production at Coke Plants. ANON. (*U. S. Geological Press Survey Bulletin* No. 254.)—In response to the unprecedented demand for high explosives a new industry, the recovery of benzol and toluol, suddenly sprang into existence in the United States in 1915. Benzol and toluol, indispensable raw materials from which explosives, dyestuffs, and other chemical products are manufactured, are oils similar to gasoline in appearance and smell and are present in the gas that is driven off from coal when it is made into coke. Before the European war the demand in the United States for these products was so small and the price so low that but one company engaged in coke making sought to recover them on a large scale. Late in 1914 the price of benzol, and particularly toluol, rose to such a point that many other companies began to build plants to recover these oils, which were then being burned with the gas, and by the end of 1915 there were 19 new plants for benzol recovery in operation and others in course of erection.

Reports made to C. E. Lesher, of the United States Geological Survey, by all of the by-product coke plants in the country, indicate that the output of benzol and other light oils in 1915 amounted to 13,942,763 gallons, in connection with which there were produced 761,256 pounds of naphthaline, a solid crystalline substance. Some of the benzol-recovery plants, which consist essentially of a complicated system of absorption towers, pumps, stills, and storage reservoirs, were in operation at the beginning of the year, but many were built during the early months of 1915 under contracts calling for great speed in erection. Several of the plants are not equipped to separate the different oils found in the crude, and 7,322,670 gallons, more than half of the total output, was reported as crude benzol and light oil and was shipped in tank cars to refineries connected with powder works and other chemical industries. In the 6,620,093 gallons of oils refined at the place of recovery, there were 4,833,939 gallons of 100 per cent. benzol, 1,315,727 gallons of toluol, and 470,425 gallons of solvent naphtha.

Thirty-one coke-making establishments with 4933 by-product ovens contributed to this total, and it is estimated that between 8,000,000 and 9,000,000 tons of coal were carbonized in the ovens that furnished the gas from which the oils were recovered. The annual capacity of the benzol-recovery plants now in operation is estimated at over 20,000,000 gallons, and with the completion of plants now building will probably exceed 22,000,000 gallons. The

value of these products is indicated by the prices currently reported during the year. Benzol, normally selling for 20 cents or less a gallon, in September brought as high as $1.25 for immediate shipment and 65 cents on contract; toluol, with a normal price of 25 cents, was sold for as much as $6 a gallon for immediate delivery and was contracted for at $4.25 per gallon.

Benzol is an excellent motor fuel. The United States, whose output of gasoline is estimated in 1914 at 30,000,000 to 50,000,000 barrels (1,500,000,000 to 2,500,000,000 gallons), stands in no need of additional supplies for this purpose. There is, however, in the United States in normal times a large use for dyes and chemicals, such as carbolic acid, which depend upon benzol and toluol for raw material and which have in the past been largely imported from Germany either as finished or as intermediate products.

After the war demand for explosives is over and the price of benzol returns to normal, serious effort will, of course, be made to find a market for this product. Shut off from European competition, the dye and chemical industry in the United States is now making rapid strides forward. If this industry after the close of the war is able to hold its own against the highly-developed foreign competition it may completely absorb the output of benzol and add another source of income to the coke-oven plants.

The Life and Relining of Guns. L. CRESAP. (*The Iron Age*, vol. 97, No. 1, January 6, 1916.)—The life of a gun is measured by the number of rounds fired beyond which the erosion of the bore impairs the accuracy of fire beyond permissible limits. Erosion is produced by the action of the gases at high temperature and pressure. While the time element is small, yet the gun, of course, absorbs heat. This absorption is confined to a thin film of steel on the interior surface. The local heating causes the film to expand, and, there being no room to expand naturally, due to the cooler and thicker wall, the elastic limit is passed and permanent set takes place. Upon the release of the pressure, and in consequence temperature, contraction of the film occurs, and, as it has been crushed, this contraction causes minute cracks. This process continues, the minute cracks getting larger at each discharge. As they enlarge they form by-passes for the hot gas, which tends to further enlarge them. The process continues until the inner surface gets badly roughened and the lands begin to be eaten away. Finally the bore gets so enlarged that the gases can escape, the shell does not attain its proper rotation, and the flight of the shell becomes erratic and subject to errors; when the gun no longer maintains a reasonable accuracy and it is said to be worn out.

All guns except small ones are now constructed with liners in the tube, which, when the bore is worn out, are removed and replaced with new liners. The cost of thus relining a gun can be roughly fixed at 30 per cent. of the cost of the gun. There appears

to be no limit to the number of times that a gun can be relined; hence the life of a gun is indeterminate. It is, of course, a matter of arbitrary decision as to when a gun should be relined, as the criterion depends solely on what is considered as the accuracy desirable. It is difficult to generalize on the subject. The small arms used in this country are considered to be worn out after 5000 to 7500 rounds have been fired. Small naval guns have been fired about 1000 times before they were regarded as worn out. Large 12-inch and 14-inch naval guns are considered to have a life on one liner of from 150 to 200 rounds. Low-velocity guns, such as howitzers and mortars, have correspondingly longer life than high-velocity guns of the same calibre, because the pressures they use, and hence the temperatures, are lower.

As is seen from the preceding, the power and life of guns are functions of each other. The amount of power that can be wisely sacrificed for the sake of preserving the gun is not only extremely difficult to decide, but depends on many factors, some of which are subject to national policy. Taken broadly, calibre for calibre, permanent fortification artillery can be given the greatest power, naval artillery can be given almost as great power, and field artillery only moderate power.

The Cylinder Cooling of Internal Combustion Engines. F. W. LANCHESTER. (*Proceedings of The Institution of Automobile Engineers* (London), December, 1915.)—Every problem concerning the automobile, whether it be on land, air, or water, is essentially a problem of weight saving. The heat escaping from the working fluid to the cylinder walls has to be disposed of externally, either to air or water, whichever happens to be the most readily available. It is perhaps almost unnecessary to point out that water cooling, when used on automobiles and aëronautical machines, is in reality indirect air cooling, inasmuch as the water merely acts as a carrier of heat between the cylinder walls and the cooler or so-called radiator. Thus the underlying principles of radiator design, so far as they relate to air passages and cooling surface, are identical with those involved in the design of the ribbed jacket in the direct air-cooled engine.

The importance of weight saving, great as it is in ship building and railway work, still greater as it is in the design of the road automobile or motor car, becomes paramount in the flying machine or aëroplane. The cooling question, therefore, as applied to the road automobile and the flying machine, is one that must be considered essentially from the point of view of weight and weight saving.

The horse-power equivalent of heat dissipated in a gas engine is approximately equal to the actual horse-power of the motor. For motor-car work, the weight per horse-power of the water-cooling surface and complement of water is approximately 2½ pounds, apart

from the weight of jackets, pipes, pump, and their water content. When all incidentals are included, scarcely less than 3 pounds per horse-power can be attained in the road automobile or 1 pound per horse-power in the flying machine.

In comparison with the radiator water-cooling system, direct air cooling by means of ribs on the cylinder is subject to the serious limitation that the weight of such a system increases rapidly with the diameter of the cylinder. In fact, with cylinders above 300 mm. in diameter this system offers no advantages on the score of weight over the radiator system, but for such diameters as are currently employed for aëronautical work there appears from analysis to be a clear saving of three-quarters of a pound per horse-power.

The author is inclined to believe that radial ribs arranged lengthwise about the cylinder, provided with the necessary flow of air, offer the best solution of the problem of cooling, the direction of flow taking place from the open end of the cylinder towards the combustion space; that is to say, from the colder end towards the hotter.

Recent Vacuum Bottle Developments. ANON. (*Scientific American*, vol. cxiii, No. 26, December 25, 1915.)—The invention of the glass vacuum bottle is generally attributed to Professor Dewar, who produced it for the purposes of a container for liquefied gases. The Dewar flask consists of two glass bottles joined at the top of the neck but touching each other at no other place, the wall surface of the space between the inner and outer bottles being silvered. The space is then highly exhausted by means of a vacuum pump.

These flasks proving too fragile for other than laboratory purposes, Professor Reinhold Burger strengthened the device by inserting between the two walls little spaces or supports and enclosing the whole in an outer protecting metal shell. This improved article found a ready market as a conveyor and retainer of hot or cold liquids or foods. In spite of this improvement, however, the article was still comparatively fragile, leading to many attempts to produce these devices by using metal in the place of glass. It has remained for Mr. William Stanley, while engaged with other investigators—notably Dr. Irving Langmuir—in the study of heat insulation, to discover the cause of previous failures of the all-metal bottle and find a remedy.

A study of the action of gaseous molecules as heat carriers proved that the high insulation effect of the Dewar flask is coincident with the attainment of a very high vacuum at what might be called a critical point in the exhaustion, and rapidly increases as this already high vacuum is slightly improved. This "critical point" for Dewar flasks was found to represent a degree of vacuum so high that the mean free path of the gaseous molecules was as great as the distance between the outer and inner vacuum walls. Accepting the limitation of the lower degree of vacuum obtainable in a metal container

by the presence of occluded gases at the surface, Mr. Stanley conceived the idea that if the vacuous walls could be brought so close together that the distance between them would be equivalent to the mean free path of the molecules at a comparatively poor degree of exhaustion, a "critical point" condition could be so obtained. He accomplished this result, not by spacing an outer and inner wall extremely close together, but by filling the vacuous space with very finely divided material, itself so chosen as to be incapable of giving off or absorbing gas in a vacuum. Vessels constructed on this principle fully confirmed Mr. Stanley's conclusions, and a commercially practical vacuum bottle without the use of glass was evolved.

Museum Fatigue. B. I. GILMAN. (*The Scientific Monthly*, vol. 2, No. 1, January, 1916.)—"Museum fatigue" is an accepted evil, hitherto tacitly recognized as admitting only relief. May not a study of how it comes about suggest some means of its prevention? The plan adopted in the inquiry consisted in devising a series of simple questions relating to certain objects, mostly installed at higher or lower levels and in cases; and an observer was photographed in the act of answering them. The museum in which the photographs were taken no longer exists, but the conditions depicted are still well-nigh universal.

The pictures obtained indicate that an inordinate amount of physical effort is demanded of the visitor by the present methods in which we offer most objects to his inspection. It is at once evident that these methods form an effective bar to the adequate fulfilment by museums of the public function they aim to perform. Not even the hardiest sight-seer will long go through the contortions which the pictures indicate are needed for any comprehension of much of what we display to him. After a brief initial exertion he will resign himself to seeing practically everything imperfectly and by a passing glance. If the public is to gain more than a minute fraction of the good from museum exhibits which is theirs to give and can now be gained by the private student, radical changes in our method of exhibition are imperative. As at present installed the contents of our museums are in large part only preserved, not shown.

The Rubber Industry. A. H. KING. (*Metallurgical and Chemical Engineering*, vol. xiv, No. 1, January 1, 1916.)—No material has yet been found that combines such a degree of strength, elasticity, and wearing power as rubber. These properties make rubber especially valuable in manufacturing the various grades of hose for air, water, steam, and oil; belts; valves and other moulded articles, and tires of all kinds. A complete list of all the various things made of rubber would be almost infinite.

The first mention of this remarkable substance from a European was by Christopher Columbus, who on his second voyage of discovery (1493–1496) saw the natives of Haiti playing with balls which

he afterward learned were prepared from the gum of a tree. This gum they called cahuchu, from which the word caoutchouc is derived. Highly interesting must this gum have been to the Spaniards. By it they were able, in a crude manner, to waterproof their garments and thus protect themselves from the heavy tropical rains. They also made the acquaintance of the related substance, balata. They found shields made of balata-impregnated cloth. The same material was used in the preparation of suits which resisted poisoned arrows. In fact, such suits are now to be seen in the Spanish Museum at Madrid. This was indeed a fine forerunner of the modern balata belt.

The English word for rubber was given it by Priestley in 1770, who recommended its use for removing pencil-marks. This would likely have remained its principal use had not the discovery of vulcanization been made. Raw rubber is not suitable for proofing garments, due to the narrow range of temperature within which it is elastic but not sticky. Below 10° C. it begins to become hard, and at 0° C. it is brittle. However, it regains its former properties on warming. Above 25° C. it has a great tendency to become sticky, and if heated above 75° C. it becomes permanently tacky.

The beginning of the rubber industry dates from the discovery, in 1839, of the important process of vulcanization by Nelson Goodyear. The bicycle craze of some years ago gave it added impetus, and later the automobile. It is now an accepted fact that these machines cannot be comfortable without pneumatic tires. It has been estimated that at least 85 per cent. of all rubber used in manufacturing goes to tires and only 15 per cent. to mechanical goods. The United States alone uses about 100,000 tons of crude rubber per year.

Increased Arsenic Production. ANON. (*United States Geological Survey Press Bulletin*, No. 251, December 31, 1915.)—The year 1915 saw another increase in the output of white arsenic, and the estimated production for the twelve months is reported by the United States Geological Survey to have been 5195 tons (of 2000 pounds), with a value at the smelters of 2 cents a pound, or a total of $207,780. The estimate by Frank L. Hess is based on the known production for the first ten months of the year and the probable output during November and December. This output is an increase of more than 11 per cent. over the 1914 production and 65 per cent. over the 1913 output.

All white arsenic made in this country is a by-product in the smelting or refining of the non-ferrous metals, and naturally the larger part is saved at the western plants. The demand is far below the possible production, which could probably be made treble or quadruple the present output if prices were sufficiently encouraging.

The largest uses for arsenic are in the manufacture of insecticides, such as Paris green, lead arsenate, etc.; in glass making, and as a weed killer. Small quantities are used in shot, medicine, and dyes.

Commercial Lighting. E. M. COLQUHOUN. (*American Gas Light Journal*, vol. civ, No. 1, January 3, 1916.)—Commercial lighting embraces the lighting of stores, factories, churches, halls, and other places of a public or semi-public nature. It is in this field, since the introduction of electric lighting, that gas has met the most severe competition. In efficiency which leads to economy, gas has always successfully met electric competition, but the advantage of economy in operating costs, formerly so beneficial to the gas industry, does not exist to the same extent to-day.

In considering the comparative costs of illumination by gas and electricity, there must be taken into account the cost of gas or of electric energy, the efficiency of the units used, and the cost of their upkeep. A few years ago the average medium-sized store could be illuminated by three upright arc lamps at a cost of $76 per year, including gas and maintenance. The cost to illuminate such a store by electricity with carbon lamps was about $385. The inverted gas arc lamp made it possible to light a similar store for $55, compared with $95 using tungsten lamps. To-day, with the most efficient units available, the cost would be $51 for gas and $60 for electricity.

In these comparisons gas is figured at $1 per 1000 cubic feet, and electricity at 10 cents per kilowatt-hour; and, while it is true many companies are selling gas much lower than $1 per 1000, it must be recognized that electric companies have largely adopted the demand system of charging for current, and, though the base rate for a few hours' burning may be 10 cents per kilowatt-hour, the excess after one hour's average daily burning is secured at a much lower rate. For the average commercial installation this would mean that the low rate would be secured for the current used in excess of $3 per month, and in many instances much less than this amount. The newer lamps, with their lessened demand, will result in a still lower amount to which the base rate will be applicable. However, the costs of illumination with gas and electricity have been decreased principally by the increased efficiency of the lamps. To-day 32 candle-power is secured with one cubic foot of gas, as compared with 17 candle-power a few years ago. The increase in efficiency of the electric units has even exceeded that of the gas units, and it is now possible to secure 13 candle-power with a consumption of 10 watts, where a few years ago it was necessary to use 10 watts for 3 candle-power. These figures show that the advantage of low operating costs for gas has decreased materially.

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